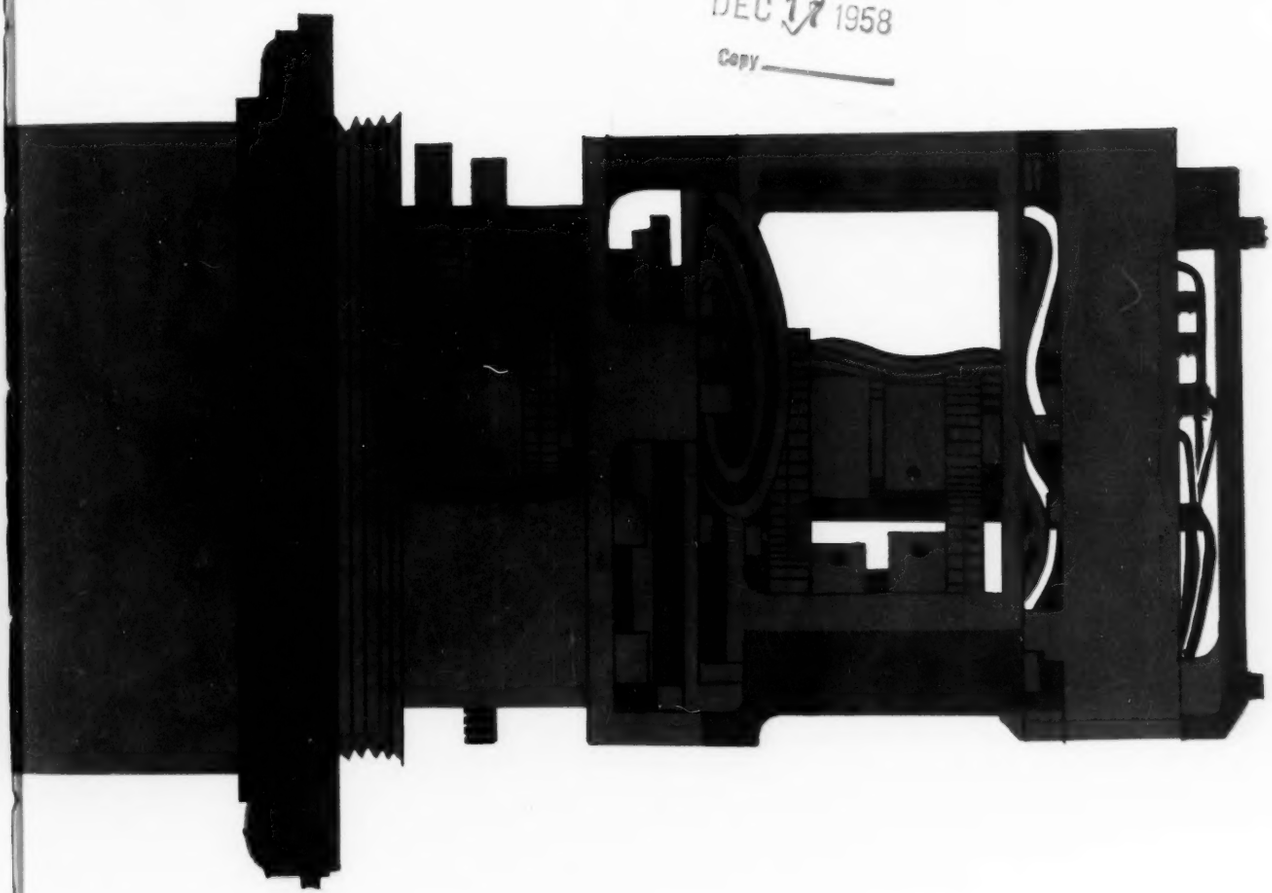
NOV 25 1958

B 744814

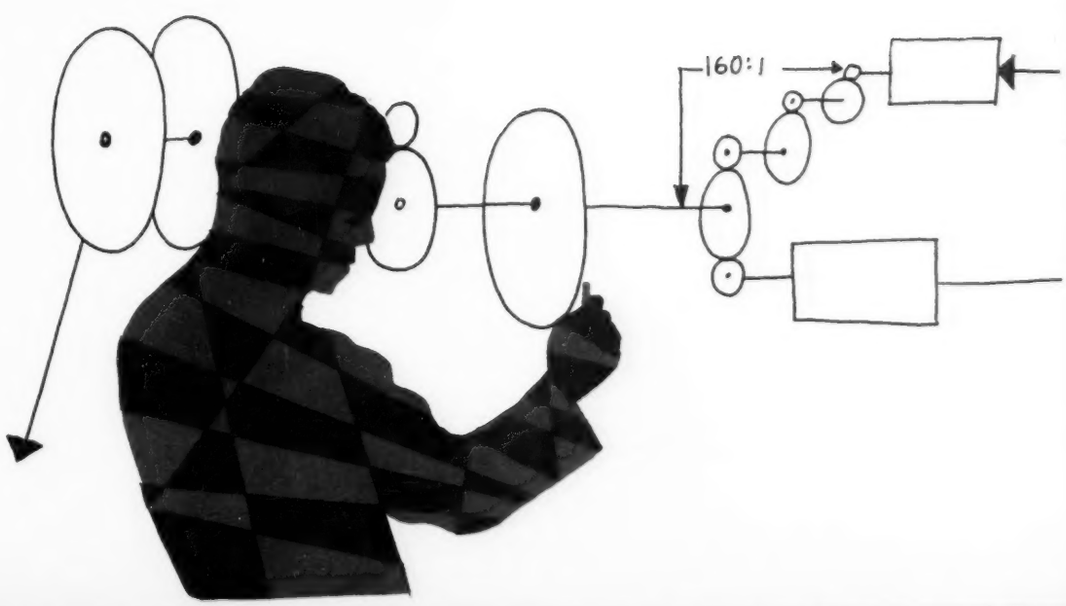
ELECTROMECHANICAL components & systems DESIGN 5

APRIL 1958

THE LIBRARY OF CONGRESS SERIAL RECORD
DEC 17 1958
Copy



Double Brush System Permits Multiple Disc Design for Increased Accuracy and Small Size in a New Sine-Cosine 7-Bit Analog-Digital Converter



THE PRODUCTS OF THE MIND

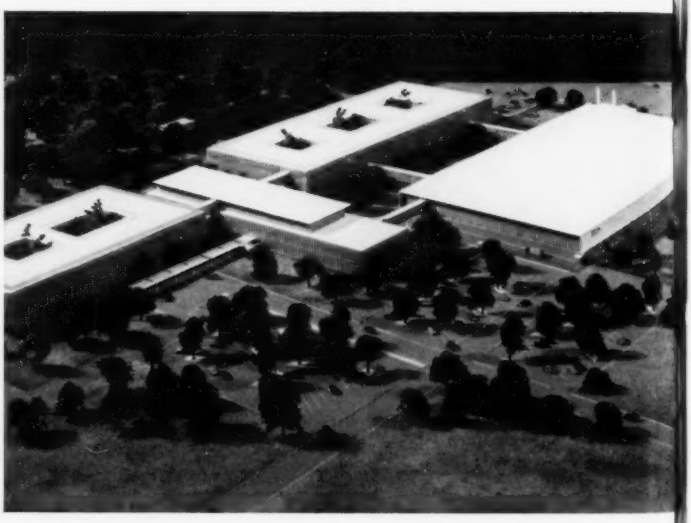
The world we live in is in large part the product of the scientific thought and accomplishment of the past, translated into engineering achievements. Whether we continue to go forward depends on whether the scientific curiosity, the imagination, the careful thought, and the logical analysis of the past, upon which today's technical achievements were built, can exist and flourish in the environment of the new world.

At Avco Research and Advanced Development Division, and at other places in the free world, an atmosphere exists in which the inquiring mind may live and create. We have the technical assistance and the facilities by which ideas are converted into concrete accomplishments. Many things have been done, and infinitely more remain to be done—the world of scientific thought is unlimited and promising. From the products of the mind will come the technical world of tomorrow.

Sidney L. Simon

Dr. Sidney L. Simon
Assistant to the President

Dr. Sidney L. Simon



Pictured above is our new Research and Development Center now under construction in Wilmington, Massachusetts. Scheduled for completion this year, the ultramodern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division.

Avco Research and Advanced Development Division now offers unusual and exciting career opportunities for exceptionally qualified and forward-looking scientists and engineers.

Write to Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Division, 20 South Union Street, Lawrence, Massachusetts.

Avco
Research & Advanced Development

NOV 26 1958

B 744814

5

ELECTROMECHANICAL

components & systems | DESIGN

CONTENTS

COMPONENTS DESIGN

4 ADJUSTABLE GEAR REDUCER FOR CONTROL SYSTEMS
Gear reducer design permits speed ratios to be changed under full load

8 ELECTRONIC CHOPPER
Switches linearly or chops voltages over a wide dynamic range

10 METER RELAY
A simple and inexpensive method for controlling rate and magnitude of a change in any variable that can be measured electrically

12 TRIMMER POTS
So small—16 to the square inch, 500 per lb.

14 SEMICONDUCTOR DEVICES
New developments in true-power silicon transistors, power switches, solid state multiplier and a miniature rectifier that operates red hot

16 SILVER-ZINC BATTERY
Increased power with a new design

18 DIFFERENTIAL METER
Gyro design techniques develop precision instrument for monitoring or controlling current, voltage or power

SYSTEMS OF COMPONENTS

24 INCHWORM MOTOR
Magneto stricture forces actuate linear feed mechanism

27 THERMO-ELECTRON ENGINE
Atomic heat converted to electricity without moving parts

30 EYETRON
A new system that converts microwave radio energy into visible light

32 ANALOG TO DIGITAL CONVERTER
Double brush design eliminates ambiguity in generating a sequential binary code

35 AMMONIA-TYPE MASER OSCILLATOR
Better than one part in one billion stability

36 3-D VIEWING
Lenticular screens simulates 3-d images without the aid of optical devices

39 MITE TELEPRINTER
High speed printing without high speed mechanical motion

42 MICROPHOTOGRAPHY
Stopping fast transient events with a magneto-optic lens

NEW TECHNIQUES

46 NEW MACHINE TOOL SYSTEM
Punched tape and transistorized computer convert blue-prints into machined parts

RESEARCH

50 RESEARCH EQUIPMENT
Superpressure made easy

51 HI-TEMP RECORDER
New developments in recording oscillograph for aviation testing

53 SPECTROSCOPY
VHF radio waves measure behavior of electrons

DESIGN TIME SAVER

56 STRESS ANALYSIS IN FINNED DESIGN

MANAGEMENT

60 EUROPEAN COMMON MARKET
Wanted for export: U.S. products, processes and know-how

LETTERS 2
EDITORIAL 3
ADVERTISING INDEX 63

Vol II No. 3
April

← CIRCLE 1 ON INQUIRY CARD

STAFF COLUMNISTS

22 David Bandel • NUCLEAR BATTERIES

44 Sidney A. Davis • DAMPING FACTORS — Entomology in Design

48 Jesse E. Hobson • RESEARCH FOR LONG RANGE PLANNING

54 Ronald C. Vickery • CHEMISTRY OF COMPONENTS
Free radicals: energy source for space travel

64 Herbert F. Spirer • SIX SIMPLE STEPS TO UNRELIABILITY

SMART ENGINEERS GET FAST RECOGNITION BY...

MAKING MANAGEMENT TAKE NOTICE

with cost reducing ideas saving up to 70% by using LOCTITE in place of sems, lock washers and other mechanical locking devices.

GIVING PURCHASING SOMETHING TO SHOUT ABOUT

by eliminating stocking a wide array of shapes and sizes of locknuts and washers. LOCTITE Liquid Sealant "fits" all threaded parts—and a bottle goes a long, long way.

TAKING THE HEADACHES OUT OF PRODUCTION

by eliminating press fits, staking, and high-driving torque tightening . . . permitting looser tolerances, reducing rejects and speeding production.

• • • •

LOCTITE treated fasteners come off *only* when you *take them off* . . . giving maximum product reliability. Four strengths provide any required locking torque. LOCTITE seals against oil, military fuels, gases under high pressure.

Write for complete details.

LOCTITE® SEALANT
AMERICAN SEALANTS COMPANY
109 Woodbine St., Hartford 6, Conn.

CIRCLE 2 ON INQUIRY CARD

LETTERS

DEP'T. OF AMPLIFICATION

(Computer Division)

Ann Arbor, Michigan

I have just encountered your magazine (Jan.-Feb. '58 issue) and I am very impressed with it; to add to my enjoyment, the lead article was on my favorite subject, and further, it concerned the most recent activity of a company whose products always display an imaginative approach to the intriguing subject of analog computers.

However, as I read this article, a number of questions occurred to me, several of which I would like to discuss.

First of all, if one were to propose the two principle philosophies of analog computing, I would like to suggest that they might better be described as the mathematical and the simulation concepts. The mathematical concept utilizes three types of linear computing elements—summing amplifiers, integrating amplifiers and coefficient potentiometers—whereas the simulation concept uses high-gain d-c amplifiers so mounted that input and feedback impedances can be readily patched into the computing complex. Now, "principle" is used in this context because for many years there was a lively competition between the companies who manufactured computers representing these two "philosophies"; the basic soundness of both arguments has been reflected recently by the fact that both of these groups have moved to a computer format which makes use of *both* principles.

The loading of potentiometers is, of course, a problem which is encountered in the use of most analog computers. However, it should be observed that it is not always required to utilize the various schemes which exist to compensate for these loading effects. As a matter of fact, the techniques in use are so simple to use that most analysts use them even when the degree of accuracy thus achieved is not required. It should be observed that the principle of pre-calibrating coefficient potentiometers has been in use on commercially available analog computing equipment for many years.

The maximum coefficient of the potentiometer-amplifier combination is not unity, of course, but is determined by the ratio of the feedback and input resistors. Also, the argument Mr. Sheingold introduced regarding inverters does not appear sound to this reader for the following reasons:

a) The "Universal Linear Operator" employs an "inverter" which in some instances may not be used.

b) *A priori*, it is not clear that the Universal Operator offers any saving in equipment—for example, the circuit shown in Fig. 3b involves the use of three amplifiers, whereas that in Fig. 3c contains four amplifiers.

c) One can imagine that in many situations, both positive and negative values of some signals will be needed, requiring a Universal Operator to be used in place of a simple inverter; the difference in cost between the two kinds of equipment is obvious.

Two further comments on the Figures: The note on Fig. 2 " . . . n may have values 0 or 1 . . . " seems to refer to the equation shown in the advertisement inside the front cover. On Fig. 3a, the relation between the "set" into the integrators and the initial conditions into the following summing amplifier is not clear.

Let me conclude by saying that two features of the "Universal Linear Operator" are certainly noteworthy: The three-dial decades for all parameter settings, and the "plus-off-minus" switches for the coefficients.

Both features add much to the convenience of using the computer; however, associated with this convenience is an added cost which must be considered. Accuracy, also, always has a price tag attached to it, and the user of analog computing equipment must always strike a careful balance between convenience – and accuracy – and the price he must pay to get them.

A. Lange
Bendix Aviation Corp., Systems Division

Editor's Note: Mr. Lange's letter was forwarded to Mr. Sheingold of George A. Philbrick Researches, Inc., whom we interviewed for the story on the Universal Linear Operator. Here is Mr. Sheingold's answer:

Boston, Massachusetts

It is always pleasant to read these comments of your readers regarding our ideas and new products, and we welcome Mr. Lange's letter as being representative of the kind of feedback that is most often constructive.

First, I should indicate that many of the reservations expressed in his letter had been considered in rather thorough detail at the very earliest stages of development; but, properly weighed against *all* the advantages of the Universal Linear Operator concept, they have had little deterring force.

I shall beg the whole discussion of philosophies (Mr. Lange having been active in the field for many years and having many excellent ideas), except to comment in passing that *any* analog

continued on p. 62

Staff

Publisher	Harold G. Buchbinder
Editor	Robert B. Brotherston
Foreign Editor	Andrew R. MacAndrew
Associate Editor	Charlotte Kaizer
Staff Columnists	David Bandel Renato Contini Sidney A. Davis Jesse E. Hobson Israel Katz Emile Labin David A. Rich Ronald C. Vickery
Special Projects Editors	Martin Kagan David I. Kosowsky Saul Padwo Herbert F. Spirer
Contributing Editors	Herbert K. Brown H. Donald Conway Oliver Haywood Herbert Kaizer George King William Seifert
Ass't. to Publisher	Ruth Robinson
Editorial Assistant	Lillian Greenberg
Production and Technical Art	Peter Mehlich Organization
Art Director	James Flora
Reader—Inquiry	Harry Kaizer Gertrude Bandel
Director of Circulation	A. Allen Binder

Offices

NEW YORK 21 East 63rd St. New York 21, N.Y. Templeton 8-4010	Milton Berns
NEW ENGLAND 1357 Washington St. West Newton 65, Mass. Bigelow 4-9006	George Palken
CLEVELAND 5322 Kennedy Ridge North Olmstead, Ohio Spring 7-0040	Donald Murray
WEST COAST 6535 Wilshire Blvd. Los Angeles, Calif. Olive 3-3223	James C. Galloway

ENTOMOLOGY IN DESIGN

The column *Damping Factors* on page 44 of this issue introduces Sidney A. Davis as one of our Staff Columnists. Currently devoting full time to consulting electromechanical engineering, Sid Davis has worked as a design engineer in both components and systems groups at Arma Corp. and more recently as chief development engineer at Servomechanisms, Inc. His consulting design work has ranged from 0.60% resolvers to complete servos and computers and has included in many instances supervision of construction and test. He holds patents on electromechanical designs and has been a frequent lecturer on the subjects he will cover in his column.

The object of Sid Davis' column will be to help bridge the gap between finished system designs and final hardware. He will view typical components in terms of their departure from specified behavior, comparing borderline performance with performance based on good conservative design. He will emphasize those factors that the "superior" engineer would call "routine", but which often take most of a project's money. In brief, he proposes to look critically at those factors which when neglected cause a carefully thought out design to "blow fuses" when it is tested.

The Title *Damping Factors* is chosen as descriptive of these factors, which slow things down, perhaps, but which when adequately taken into account gently ease a design into workable hardware Under this column heading Sid Davis will attempt to "damp out" the unproven, the marginal and the over complex which interfere with the development of stable products.

Sid Davis does not overlook the fact that systems engineers are competing under severe operating conditions. They must push the state of their art in both application of advanced theory and use of latest components. "Applying newly developed components in the most sophisticated manner is difficult," Sid points out, "because there is little or no experience to draw upon. The theoretician must make simplifying assumptions. The components manufacturer cannot pin down every characteristic of his product. As a result, in accordance with the axiom 'If Anything Can Go Wrong It Will', a lot goes wrong. The high order terms in the differential equation (omitted for simplicity) and the secondary time constants in the servo motor (small enough to be neglected) team up with assorted non linearities to create a major development program and long project delays."

It will be these typical simplifying assumptions leading to unexpected difficulties requiring extensive debugging that Sid will emphasize in his column.

Robert B. Brotherston
EDITOR

Published monthly by Benwill Publishing Corporation. Benjamin Robert Payn, President: Harold G. Buchbinder, Executive Vice President: Milton Berns, George Palken, Vice Presidents. Executive, Editorial and Subscription Office: 1357 Washington St., West Newton 65, Mass. Telephone BIgelow 4-9006.

ELECTROMECHANICAL Components & Systems DESIGN is circulated without charge upon request to qualified research, development and design engineers in all branches of industry in the continental United States including governmental and university installations. Other subscriptions: Continental U.S., $10.00 per year; single copy, $1.00 when available.

Copyright 1958 by Benwill Publishing Corporation.

Accepted as controlled circulation publication at Orange, Conn.

Postmaster: send form 3579 to Benwill Publishing Corporation, 1357 Washington St., West Newton 65, Mass.

FIG 1—Adjustable type gear reduction unit. The overall reduction ratio may be set under load to any of 5 different values by simply resetting the knob. The typical mounting base is easily replaced by special configurations to suit specific mounting requirements.

ADJUSTABLE GEAR REDUCER FOR CONTROL SYSTEMS

Speed Ratios Changed Under Full Load

A highly precise, low backlash, gear reduction unit with an input to output speed ratio that may be easily adjusted through a range of values by the simple process of setting the position of a control knob provides a new dimension to many control system applications. The outstanding performance characteristics of the unit are its ability to change ratios, even under fully-loaded conditions, and the practically unlimited variety of speed reductions for which the unit may be designed. The precsiion built into the design for purposes of low backlash results in low operating noise, smoothness of engagement and long life. Units have been designed for various load requirements from heavy duty applications to instrument use. The unit shown in Fig 1 has 5 ratios with intervening neutral positions and a detent for positive setting. In actual applications the housing is tailored for easy integration into the control system.

Information on this unit, called a Multi-Reducer, was obtained from Mr. Haxton and Mr. Wallendorf of the Haxton Gear Company, East Rockaway, L. I., N. Y.

APPLICATIONS

The "Multi-Reducer" may profitably be applied in many of the common speed control problems. It is much more efficient than many methods of speed control which increase drive motor losses; such as, for instance, the control of wound rotor polyphase machines by adjustment of exterial rotor resistors. It permits the use of a simpler, cheaper, and more efficient type motor than those dependent on pole switching for speed change, in addition to offering a wider selection of operating speeds. Its capacity for switching reduction ratio *under load* gives it a major advantage.

It provides the most flexible speed control system when used in conjunction with drives having themselves a limited range of speed adjustment. For example, a shunt controlled d-c machine is able to provide a smooth 2:1 speed coverage with only a slight loss in efficiency. Integrating such a drive with a 5-station Multi-Reducer with reduction ratios of 2, 4, 8, 16, and 32 to 1, results in a drive having high efficiency and smooth control of output speed continuously over a range of 64 to 1. It is possible to go considerably beyond this, where required.

The Multi-Reducer makes a special contribution in applications involving very high peak loads. For example, where a driven load requires a starting torque far in excess of running torque, a large reduction can be used until the load is brought up to an appropriate predetermined speed. This permits selection of the drive-motor primarily on the basis of its efficiency and suitability for the long term portion of the duty cycle, with no compromises necessary for the sake of short-duration peak requirements. This cuts size and cost.

There are many complex variations of this simple idea of optimum duty-cycle application engineering.

Essentially, in problems of this sort, the motor, which is basically a high speed-low torque device, must be "matched" to the load, which is most often a low speed-high torque device. This "matching" process is carried out by a gear reduction unit, whose ratio is chosen to suit the specific requirements. The ratio selection is based upon two factors—the characteristics of motor and load, and the specific performance to be achieved.

For example, suppose a motor of inertia J_m is required to accelerate a load of inertia J_l in minimum time. Then, regardless of the speed-torque characteristics of the motor, the optimum gear ratio, n, will be that which equates motor and load kinetic energies. Thus:

$$\tfrac{1}{2} J_l W_l^2 = \tfrac{1}{2} J_m W_m^2,$$

where W_l and W_m are load and motor speeds respectively. The gear reduction is therefore:

$$n = \frac{W_m}{W_l} = \sqrt{\frac{J_l}{J_m}}$$

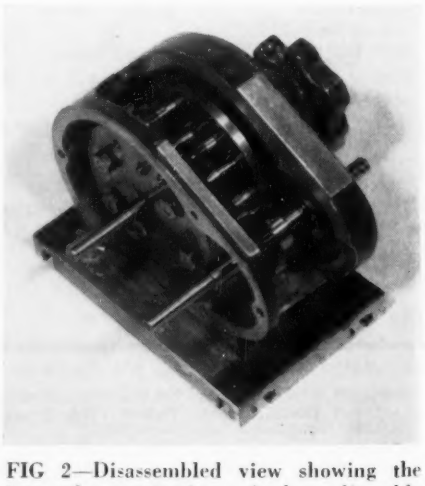


FIG 2—Disassembled view showing the internal construction of the adjustable ratio reducer.

Similarly, for friction loads or combinations of friction and inertia, and various requirements for velocity and acceleration, appropriate criteria exist for the selection of gear ratios for greatest acceleration.

At starting, the reduction should be great enough to permit smooth overcoming of the starting friction.

During the steady running condition, the reduction should be such as to permit drive motor operation as closely as possible to its maximum efficiency point.

Thus, in our specific example, at least three different ratios, for starting, acceleration, and running, could be used in sequence to optimize the behavior of the system. As a matter of fact, depending on the permissible complexity of the control equipment, and the criticalness of the application, an even greater number of ratios might be advisable with apropriate switching at discreet speeds within the acceleration cycle.

In a parallel vein, the reducer may be applied to "multiple-mode" servomechanisms, where the particular duty requirements would indicate the choice of at least two different ratios. A common example is the target-tracking problem in military applications, where a weapon may be required to swing very rapidly over a wide angular range to the approximate target position, and then to track slowly in response to radar and computer information thereafter.

The Multi-Reducer may be controlled either manually or automatically. Automatic operation may involve the use of stepping motors, solenoid actuators, gear motor drives, Geneva mechanisms, and such devices for adjusting the gear reduction setting. This automatic control suggests the greatest range of uses, where ratio may be adjusted in response to data taken from the driven load, or in a fixed time sequence. Thus, a system based on smooth rheostat control over a narrow range might be hooked up for automatic ratio switching at the high and low rheostat positions to give convenient wide range control.

The reducer may be applied, especially in the small sizes, to the simple process of ratio changing in mechanisms in many varieties designed for wide ranges. In servomechanisms, the selection of gear ratio is based upon such concepts as loop gain and stability margin, and must be proven out experimentally. When the optimum ratio has been determined by actual test, a specially designed gearhead can be substituted with the certainty of successful performance.

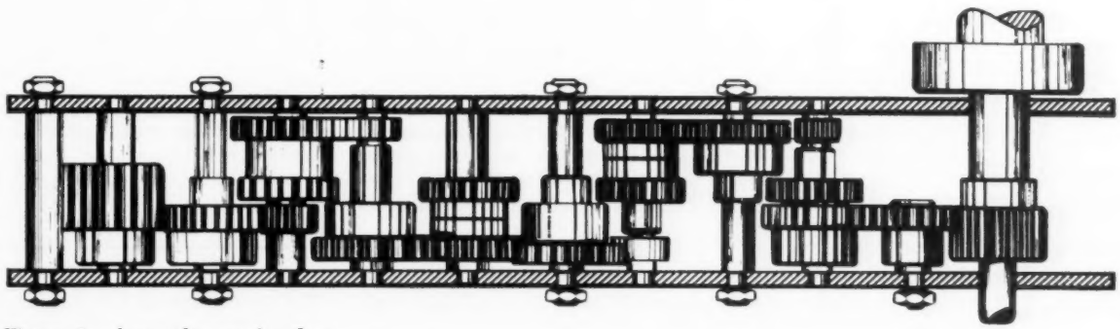
The range of application is wide. However, it is possible to divide applications into various classes. Criteria for such division include:

- Precision—for closed or open loop systems; is backlash important?
- Power level—is the load nominal or substantial?

This simple classification helps devise the most suitable detailed design specifications.

DESIGN DETAILS

Figures 2 and 3 show a disassembled view and a layout of a typical adjust-



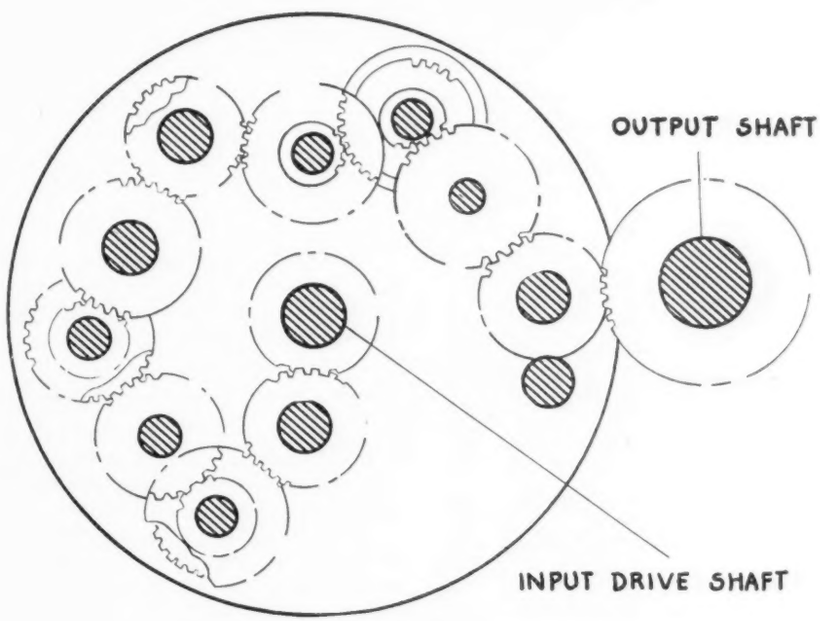


FIG 3—Figure 3a shows the gearing layout of a typical adjustable ratio reducer. Figure 3b is an elevation view showing relationship of driving gears to output shaft. To the right of Fig. (a) we see the input shaft physically located at the very center of the circular plates that support the gear bearings. Through a system of idlers, a whole sequence of output drive pinions are driven by rotation of the input shaft. Proceeding from right to left in Fig. (a), the output drive pinions rotate at successively slower and slower speeds. The output pinions are physically located around the periphery of the bearing plates in such a way that they may be successively brought into mesh by rotation of the entire bearing plate assembly, with the fixed output gear mounted in the rigid frame of the unit, see Fig. (b). This rotation is easily accomplished by an ordinary knob such as shown in Fig 1, which may be rotated by hand and secured by detents, or else automatically actuated. During actual meshing, we may visualize the output gear fixed on the frame and coupled to the load. The knob which drives the entire gear assembly will be rotated so that the next output drive pinion will be brought into mesh with the output gear. This mesh is rather smoothly accomplished because of the rotary nature of the movement. In effect, the pinion seems to "roll" into position, gradually meshing, and bringing the output gear to the new speed. While it is true that certain types of loads, under certain conditions, can cause heavy shocks, it is experimentally confirmed that the smoothness of engagement is surprisingly good.

able reduction unit indicating how the unit works. The principle is simple. Some mechanical details of the unit are:

- Ball bearings applied at the input for low friction
- Further application of ball bearings as required for reduction of friction and long life
- Distribution of lubrication by the consecutive nature of the meshes, spreading lubricant from a reservoir at the base of the unit. Other lubrication systems may be devised
- Use of sleeve bearings where cost rather than unusual performance is required
- Use of a single gear pitch and gear material in the standard models, for cost reduction. Special designs can have more than one gear pitch
- Specially shaped gear teeth having rounded contours by lengthening the addenda give smooth engagement while meshing under load.
- The ease with which the basic mechanism may be used with different housings and ratio adjusting drives
- The inclusion of neutral stations, where required.

FIG 4—Test set-up used in life-testing gears under load. Gear load torque is developed by a loading spring. With this arrangement two identical sets of gears, identically loaded, may be evaluated in an especially convenient manner. The gear pairs are chosen as representative. By means of the spring loading shown in the figure, the gear meshes may be loaded to the desired degree in a manner very similar to the preloading of anti-backlash gearing. The only power required to drive the test set-up is the friction loss in the gear teeth, permitting use of a small, lightly loaded drive motor. Also, no heavy power dissipation in a dummy load is required. Life is conveniently measured even at substantial horsepower ratings. (The Haxton reducer shown is merely used as a convenient reduction unit.) The spring, in this particular example, is set up to deliver about 250 inch-ounces of torque with a 25 degree twist. This angle is sufficiently large so that once the spring rate is actually known by test, an accurate determination of load may be made by measuring the angle of twist. Tooth wear introduces only a negligible load change since its effect on the angular orientation of the two loaded gears is relatively small.

PERFORMANCE

Backlash. The Multi-Reducer is manufactured to the close tolerances usually required for exacting applications. The 20 degree PA gears are cut to AGMA Class-2C tolerances, which result in composite errors and backlash as shown in Table I.

TABLE I

COMPOSITE ERRORS AND BACKLASH OF GEARING IN ADJUSTABLE RATIO REDUCER

(Correspond to AGMA 2C Tolerances)

Composite Errors

Class	Total Composite Error, Inches	Tooth-To-Tooth Composite Error, Inches
Precision 2	0.0005	0.0003

Backlash

Class	Diametral Pitch	Backlash* (Inches)
C	24, 32, 48	.001 to .002
C	24. 32, 48	.001 to .002
C	64	.0007 to .0015

*In two mating gears of equal tooth thickness on nominal center, measured at point of tightest engagement.

The nominal backlash in each mesh is fixed by the gear and center distance tolerances. However, the backlash contributed by each gear mesh to the over-all backlash as seen, say, at the output shaft, must be calculated by standard methods. Meshes at the low speed end contribute most to the backlash. Where closer backlash requirements must be met, it is frequently sufficient to tighten up tolerances at the output mesh. For long life under severe environmental conditions, gears of 416 stainless steel are successfully used.

Load Capacity. Table II shows the load handling capacity of these gears unhardened, and for the face widths and operating speeds indicated.

TABLE II

LOAD HANDLING CAPACITIES OF STANDARD LINE OF GEARED RATIO CHANGERS

Pitch	Face Width (inches)	Permissible Torque Load (oz-in)
64	1/8	65
48	3/16	175
32	3/16	390
24	5/16	1150

In all instances in the Table, the critical loading occurs at the highest torque mesh, which is at the low speed output. AGMA analysis of permissible loading reveals that failure will probably occur in surface durability, rather than from inadequate beam strength of the teeth. By hardening the gears in the output mesh, or using harder steel alloys, it is possible to make a very substantial increase in the permissible torque loading on the output.

While it is possible to achieve quiet and relatively shock-free ratio switching, tooth loading can be quite severe when load inertia is large and speed changes are abrupt. Where switching of high speed, high inertial loads may be required, it is advisable to choose successive ratios so as to avoid too great a speed change per stage, to switch smoothly, and to employ a drive motor whose speed will drop appreciably under momentary overloads. Based on the specific situation, tooth loads should be estimated and compared with permissible ratings.

Horsepower. Because of the adjustable reduction ratio, it is not possible to speak of a certain over-all horse-

power rating for the reducer. As a matter of fact, such a rating could be very misleading, especially for large reduction ratios. Since horsepower is proportional to the product of shaft torque and speed, regardless of the strength of the output gear, the horsepower rating would be low at very low output shaft speeds.

In actual practice where an adjustable reduction ratio between motor and load is employed, the load horsepower requirements, and usually even the *torque* requirements, diminish with load speed. (An important exception in the case of load torque occurs when starting friction is very high). As a result it is much more realistic to express the capacity of the gear reducer in terms of permissible load torque and a maximum allowable input shaft driving speed. A horsepower rating, if required, would be most logically defined at the *minimum* reduction ratio, where fastest load speed may be required. Reduction in load speed by ratio switching would then result in a reduction in horsepower output capacity consistent with a reduced demand by the load.

Although the Multi-reducer is relatively new and considerable additional experience is required, it has been operated successfully at input speeds up to 6000 rpm with smooth ratio changing and satisfactory wear.

Life and Wear. To determine true performance limits with respect to life and wear, the life test set-up of Fig. 4 has been designed. A life test carried out on 32-pitch gears on this test set-up at 50 rpm and 250 ounce-inches load revealed negligible wear at the end of 1000 hours, and very little wear 4000 hours later.

Gear Friction. The life test set-up of Fig. 4 also provides a convenient means of measuring gear friction. Friction is approximately proportional to the torque loading. In a ball bearing unit operating near rated capacity, the friction loss is approximately 5 percent per stage.

The single stage friction may be translated into an over-all friction figure for the entire unit by inspection of the gear layout diagram. If it is assumed that friction approximately is proportional to torque loading, friction torques will be greatest on the high-torque low-speed shafts, and vice versa. Since torque loading on each gear is inversely proportional to its speed for a fixed horsepower transmission through the gear train, the horsepower lost per stage per transmitted horsepower is approximately constant. Thus, under rated load conditions, the frictional horsepower may be determined from a per unit stage efficiency figure, η_{is}. For n stages, the overall efficiency is $(\eta_{is})^n$. With this figure the fraction of input driving power that ultimately reaches the load may be estimated. The remainder, frictional loss within the speed changer, may be assigned by equal division to each of the successive ratios in the train. Efficiency becomes poor when a great many stages are included in the train.

While these efficiency figures are inaccurate at light loads, this operating condition is generally not critical. The use of sleeve rather than ball bearings will increase stage friction, and reduce efficiency. The unloaded gears in the loaded unit, set at a particular ratio, which follow the output gear, contribute little friction since their no load friction loss is low, and they rotate relatively slowly.

Effective Inertia. In closed loop systems, or those involving rapid accelerations and load reversals, it is frequently important to minimize inertia. Inertia may be introduced into the system by the Multi-Reducer gearing itself. It is necessary, in determining the effective system inertia of a device like the Multi-Reducer to consider not only the inertias of the individual gears, but also the relative speeds at which they operate. Thus a high speed gear will contribute a lot more kinetic energy (and *effective* inertia) to a system than an identical low speed gear. The contribution in terms of inertia is directly proportional to the square of the speed. For simplest results, it is often assumed that face widths are equal and the densities of the material used in all gearing are also equal. Since the inertia of a cylindrical shape varies as the fourth power of the diameter, all small diameter elements such as shafts, hubs, bearing races, and the like are assumed to have negligible inertia. The effect of gear tooth form is averaged out by assuming all gears are cylinders of O.D. equal to the corresponding pitch diameter. It is almost always the case that only the higher speed gears contribute significantly to the effective inertia.

The inertia contributed by the Multi-Reducer at its input shaft is constant, regardless of ratio setting, since even idling gears contribute their fixed amount. The effective output inertia will be greater than the input inertia in proportion to the square of the reduction. The output inertia will vary with the reduction, being a maximum for the lowest speed setting. But of course, at low speeds, the output inertia will not carry excessive kinetic energy.

The gear on the load shaft must always be considered part of the load inertia.

Circle No. 160 on Inquiry Card

SPECIAL AND STANDARD

POLLAK

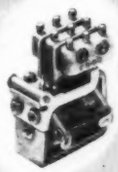
RELAYS, SOLENOIDS & SWITCHES

Whether your application demands a special or standard design, our engineering experience and production facilities are geared to meet your demands.

Write for Technical Bulletin EM.

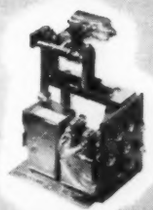
High Voltage Switching Relay, Model RL-906, for Radar, Sonar and Missiles applications.
Size: 3 5/16"x4 15/16" x1 5/8"

High Voltage Switching Relay, Model RL-904, Bu-ships rated Discharge Switch.
Size: 4 15/16"x6 15/16" x4 11/32



D-C Miniature Relay Model RL-503ES, 5% Differential between Pull-in and Drop-out, Open or Hermetically sealed.
Size: 1 3/8"x1 1/2"x 1 5/8"

D-C Miniature Solenoid, Model SO-151, High magnetic efficiency for improved power-to-size ratio.
Size: 1 7/16"x3 1/32"x 3/4"



Vacuum Switch Relay Model RL-1011, for High Voltage applications up to 10KV at 5 amps. (live switching)
Size: 4 3/8"x4 1/8"x 4 15/16"

Since 1909
JOSEPH POLLAK CORP.
75-95 Freeport Street
Boston 22, Mass.

CIRCLE 3 ON INQUIRY CARD

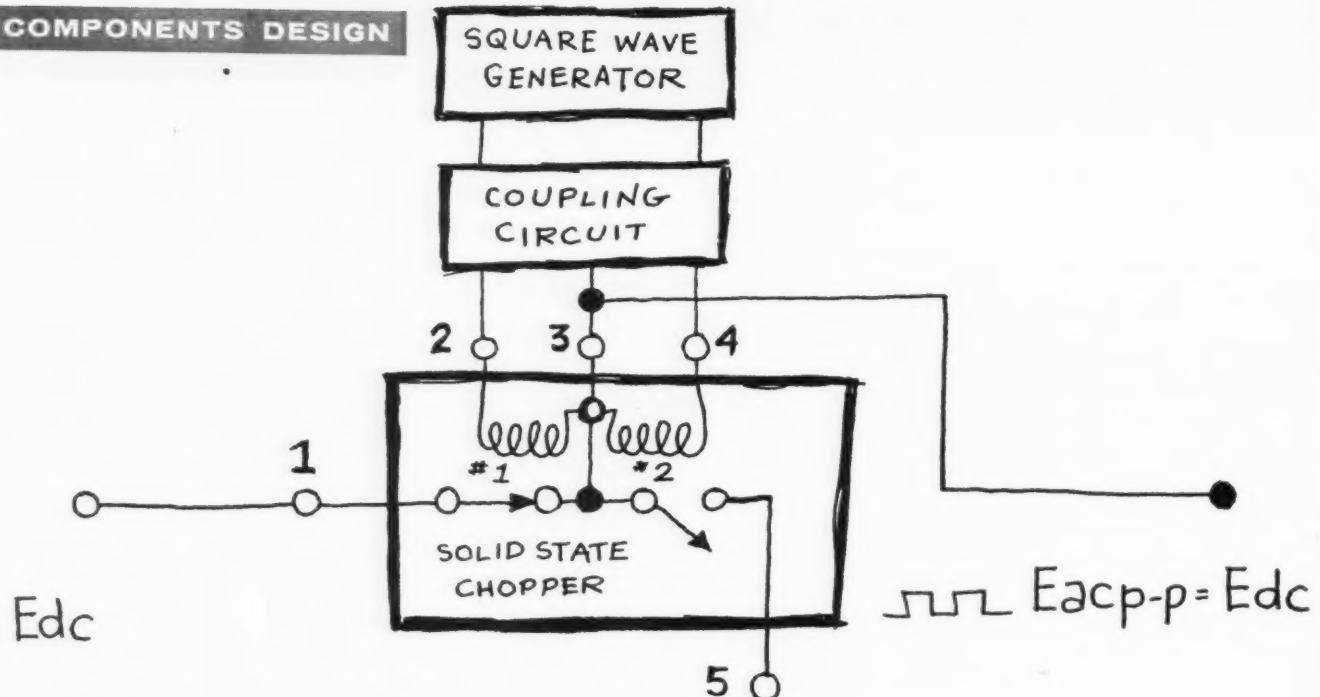


FIG 1—Equivalent switching circuit for solid-state chopper. The switching action of the matched transistors is represented as two relays. The square-wave generator is shown as alternately driving the relays so that when one relay is closed, the other is opened. In this manner, the signal source is alternately connected to the load by relay No. 1 every half cycle, while relay No. 2 is open. During the other half cycle, the load is disconnected from the source as relay No. 1 is opened and the load is shorted by relay No. 2. As a result, the output across the load will be a square wave having a peak amplitude equal to the input voltage during every half cycle, and zero voltage during the other half of the cycle.

ELECTRONIC CHOPPER

Inertialess Device Operates from D-C to Hundreds of Kilocycles

A new electronic chopper, or modulator, that uses a matched pair of transistors alternately switched on and off to alternately connect and disconnect a load from a signal source has been developed by Solid State Electronics Co., Van Nuys, California. It may also be used as a demodulator to convert an a-c signal to d-c.

Although a single transistor can be used to accomplish the same functions, the use of a matched pair connected in the proper manner has the advantage of a lower signal null in the order of tenths of a millivolt or less and also provides a much greater degree of drift stability over a wide temperature range.

The new chopper is capable of linearly switching or chopping voltages over a wide dynamic range that extends down to a fraction of a millivolt. Unlike mechanical choppers which can only be designed to operate over a narrow and comparatively low frequency range due to mechanical limitations, this transistorized chopper is an inertialess device that can be driven from d-c to hundreds of kilocycles. Accordingly, the voltage to be modulated may be a time varying function somewhat slower than the chopping frequency.

Drive for the chopper is best

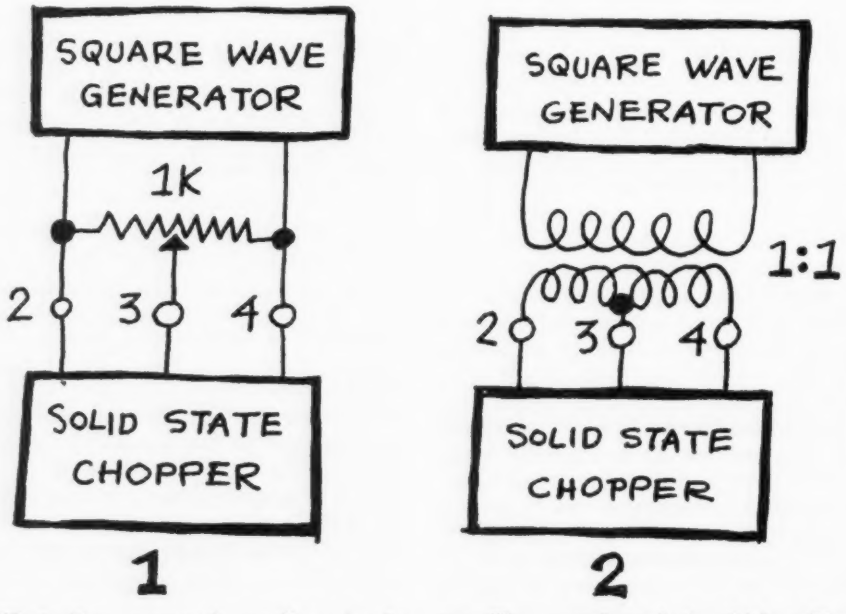


FIG 2—Two suggested coupling circuits for driving the solid-state chopper. The first method is not limited by the frequency response of the transformer, but does require a slightly greater drive voltage. The second method, which utilizes a transformer with a center-tapped secondary, has the advantage of isolating the square-wave generator should grounding of the square-wave generator be required.

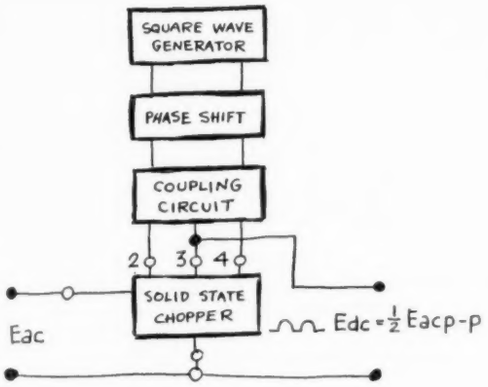


FIG 3—Half wave demodulator.

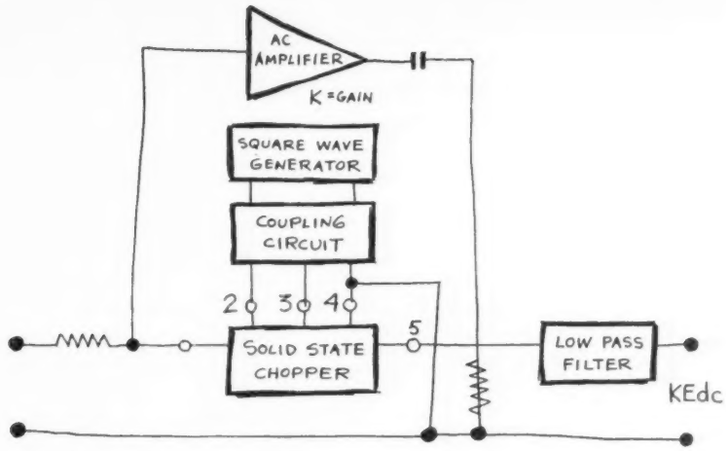


FIG 4—Combined modulator and demodulator for amplifying low level d-c signals.

supplied by a square wave generator. However, other waveforms, such as a sine wave, may be used for driving the unit in certain applications where a small amount of ripple is not objectionable. The switching circuitry used (see Fig. 1) operates the transistors in a manner that provides stability and freedom from drift over a wide temperature range. The output of the square wave generator should be double-ended (ungrounded) when coupled to the chopper. Two driving circuits are suggested in Fig. 2.

The noise figure of the solid-state chopper is competitive with mechanical choppers for many uses. Furthermore, the noise level will not increase with usage.

A solid-state chopper accomplishes synchronous half wave demodulation as shown in Fig. 3. In this maner, out of phase signal components can be discriminated against.

Figure 4 shows how a single solid-state chopper can be used, first to modulate, and then to demodulate a low level signal, so that the advantages of more stable a-c amplification can be derived without changing the d-c nature of the signal.

Figure 5 illustrates the use of a solid-state chopper for a typical servo application.

This unit is practically immune to the effects of shock and vibration making it ideal for military, missile, and portable applications; or where power conservation, miniaturization and elimination of maintenance are a necessity. The transistor chopper has an inherently long life and is not subject to contact bounce, wear, pitting or burning.

Circle No. 170 on Inquiry Card

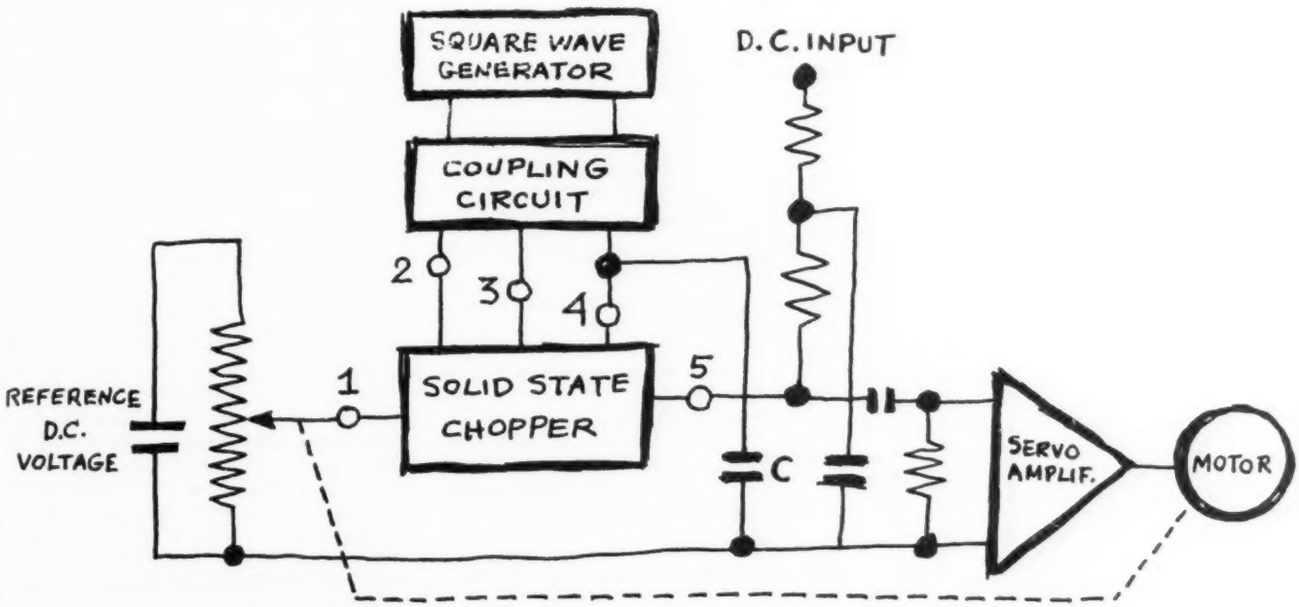
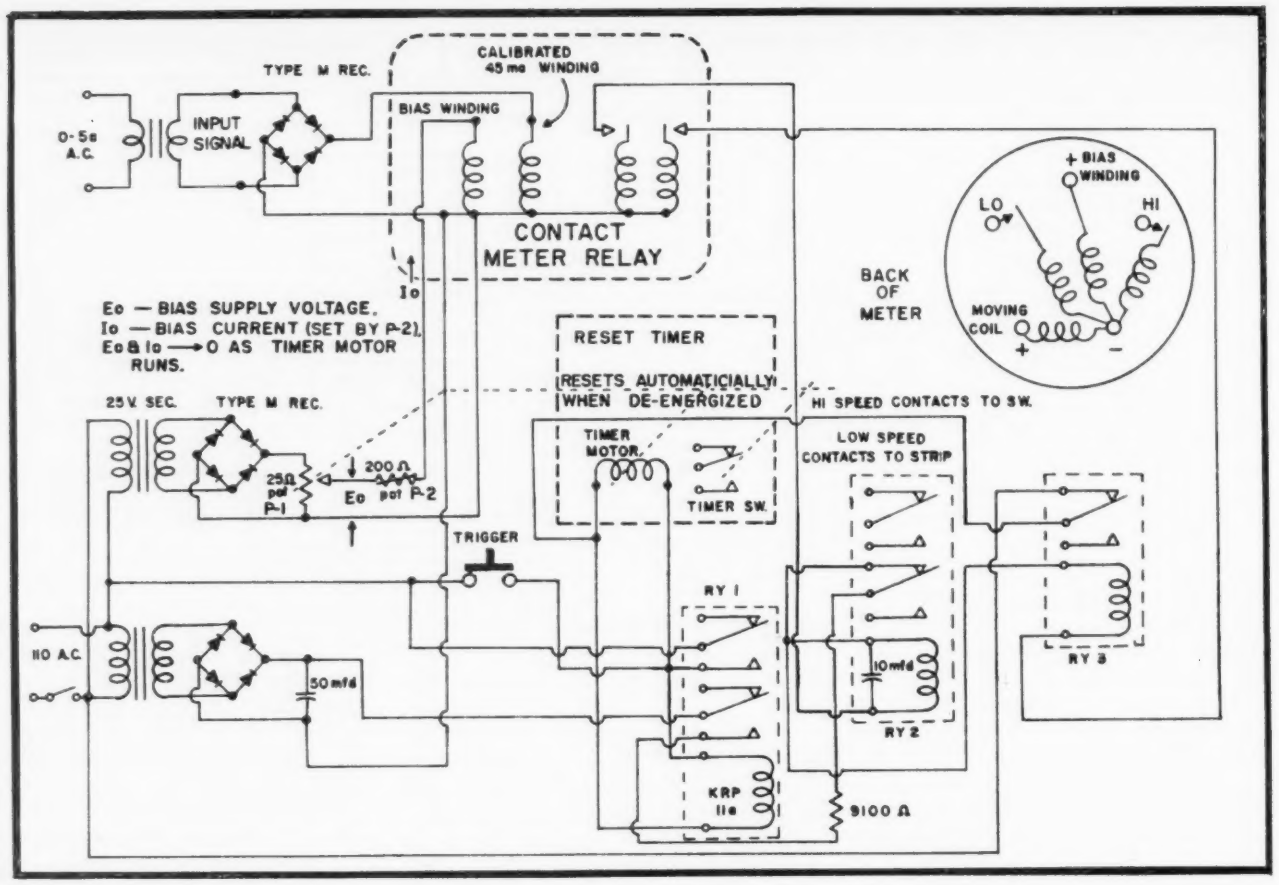


FIG 5—Application of solid state chopper to fast response servo system. The higher frequency operation of the transistorized chopper speeds up the response time of the servo far beyond the limitations imposed by mechanical choppers. The solid-state chopper continually samples the reference d-c voltage and charges the capacitor C to this reference level. The chopper also alternately samples the d-c input. Any difference in potential between the reference and the input causes an a-c signal to appear at the input to the a-c servo amplifier. The amplifier then drives the motor in such a direction as to cause the reference voltage to be equal to the input voltage, at which time the motor will stop. The a-c servo is, thereby, made to follow the d-c input.



METER RELAY

Compares Signals and Initiates Control

A simple, inexpensive method of controlling the rate and/or magnitude of change of a variable has been obtained by use of a circuit built around a new kind of contact meter-relay action. It applies to any variable that can be measured electrically.

The circuit accomplishes the same programming effect as a closed loop pulse servomechanism, but much more easily. It is believed to be the first control circuit to apply a feedback signal directly to a meter-relay as a means of guiding control action. Programming can be set up by means of cams, punched tape, or any other common method.

The circuit introduces a relatively uncomplicated electromechanical device into a field hitherto reserved for complex electronic hook-ups. It is expected to lead to widespread use of meter-relays in programmed operations, since the meter-relay performs the two functions required in any programming set-up: signal comparison and initiation of control action.

The meter-relay signal is absolute and direct, moreover, without the distortion or drift that results from the amplification necessary in an electronic hook-up. At the same time the meter-relay retains its familiar advantages of indicating the signal and permitting easy adjustment of signal limits.

In this variation of a new circuit developed by Assembly Products, Inc., Chesterland, Ohio, the rate of change of a variable is being controlled automatically. The variable is motor current, expressed in a-c amperes. Key to operation of the circuit is a new kind of contact meter-relay, called a "differential" type, which has two moving coils instead of the usual one. Polarity of the coils is such that the single indicating pointer shows the sum of the signals passing through the two coils. The sum remains constant, so that if one signal decreases, the other increases. In this case a bias, or false, voltage is being produced internally in the control. It, in turn, is impressed on the bias winding of the differential meter-relay. (The amount of this bias signal can be controlled at will. Here it is set at a point from which it will be completely dissipated in the time interval of the cycle.) The bias signal is impressed across a 25-ohm potentiometer which is linked mechanically to a timer motor and reset mechanism. When the cycle begins with the momentary closing of the trigger contacts, No. 1 relay closes and is held in through the contacts of No. 3 relay. Closing of No. 1 relay impresses 115 volts a-c on the timer motor, which begins to run and to reduce the bias signal to zero in its preset time interval. The low adjustable contact on the meter-relay has been preset to the original amount of the bias signal. Therefore the reduction of the bias signal by the timer motor results in meeting and locking of contacts on the indicating (signal) pointer and the low adjustable pointer. The low pointer contact is connected into a double-pole, double-throw relay, No. 2. When this relay is actuated it produces a pulsing signal. Time of pulsation depends on the size of the capacitor across the relay's coil. The pulsing signal from No. 2 relay is impressed on a universal fractional horsepower a-c motor which is connected to a Variac. Output of the Variac controls the device, and a current from the device feeds back as the input signal. Since the differential meter-relay maintains the sum of the signals in its two coils, the feedback current is increased at the same rate the bias signal is reduced. At the end of the preset timing run, the timer switch closes and the fractional horsepower motor is put into high speed. This high speed was preset by a resistor in series with the motor. Output of the Variac is then increased quite rapidly up to the high limit on the meter relay. When the high contacts close, No. 3 relay operates, opening No. 1 relay and resetting the timer. The next cycle begins with momentary closure of the trigger contacts.

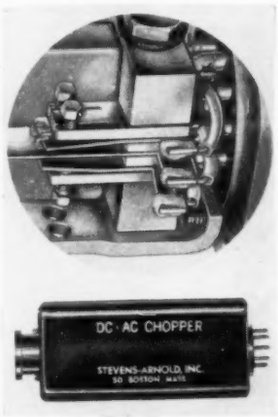
The circuit is so sensitive that a tiny fraction of the signal may represent a full scale movement of the pointer on the meter relay.

Circle No. 152 on Inquiry Card

Miniature DC-AC Choppers With Twin Contacts

Miniature dc-ac choppers feature a novel twin-contact arrangement that provides increased reliability. The two independently adjustable, parallel connected contacts make a total of four contacts for SPDT and eight for DPDT. Case size is 1¼ inches x 1 inch x 2 11/16 inches. Electrical noise and thermal emf's are virtually eliminated through the use of a Mu-metal case, effective internal shielding and a novel plug-in low loss base with gold plated pins. Stevens-Arnold, Inc., South Boston, Massachusetts.

Circle No. 105 on Inquiry Card



Binary Timer or Code Generator

A new binary timer provides 128 binary counts at a rate of one per second continuously. This serialized counting technique codifies the time base in sampling or telemetering systems for simplifying data reduction. The 8-bit binary coding is continuously available for use in digital computers, programmers and control systems. The binary timer is an integrated design, comprising a new type commutator and brush assembly and low-inertia gold-plated code drums driven by a qualified 28 volt d-c chronometric-type motor in a case only 2½ inches in diameter by 6⅝ inches long, weighing 2.3 pounds. Hermetically sealed, RF filtered and of ruggedized airborne quality, this unit meets military, industrial and laboratory requirements for a precision binary encoded timing unit.

Each data frame or second of time contains a synchronizing commutator pulse, followed by an identifying 8-bit binary encoded train of pulse. The sync pulse initiates the second and the binary coding identifies it. Repetitive cycles of the 128 bits can be recognized by a simple counter or special sync pulse coding. Instrument Development Laboratories, Inc., Attleboro, Massachusetts.

Circle No. 106 on Inquiry Card

Miniature 60 Cycle Servo Motor

A servo motor 1.062 inches in diameter has been developed for applications where only 60-cycle power is available and rapid response is necessary. The 4.5-oz size-11 unit develops a stall torque of 1.0 oz-in and will achieve an acceleration at stall of 59,000 radian/sec/sec. Moment of inertia is 1.2 g-cm² and time constant is 0.0057 sec. If required, the control phase of the motor may be wound for optimum performance with a direct transistor drive. The unit is also available with gear trains of the same diameter. Ratios may range from 1:10 to 1:2187. Maximum backlash will not exceed 30 minutes. The motor is available as a unit, as a servo assembly combining synchros, amplifiers, gear trains, and accessories such as slip clutches, cams, internal stops, switches and so forth. Daystrom Transicoil Corp., Worcester, Montgomery County, Pa.

Circle No. 107 on Inquiry Card

Drain Valve

Self-operating drain valve reduces corrosion in pressurized ducts by removing the water as it accumulates in low spots. Inside the stainless steel body, a tungsten carbide ball blocks the valve opening and is held in place by duct pressure. When the duct pressure is reduced below 10 psi by system shut-off, a spring forces the ball out of the valve opening and allows the water to drain. An increase in duct pressure forces the ball back into the closed position. Barber-Colman Co., Rockford, Illinois.

Circle No. 108 on Inquiry Card

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

types: ALL INSULATIONS
including polyvinyl chloride; asbestos; silicone rubber; Teflon; Kel-F; polyethylene; Nylon; etc.

conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

source: CONTINENTAL WIRE CORPORATION

For complete information on the many types of Continental insulated wires and cables, write or call CONTINENTAL, Wallingford. Where heat . . . moisture . . . cold . . . oil . . . grease . . . corrosive vapors . . . demand a reliably insulated wire or cable, be sure to specify CONTINENTAL. A wide range of types and sizes in stock, or to special order. Give amperage, voltage, diameter limitations, and operating temperatures and conditions when inquiring.

continental wire corporation

WALLINGFORD, CONN. / YORK, PENNA.

CIRCLE 4 ON INQUIRY CARD

FIG 1—Minelco Model HA-1 potentiometer made for volume control of hearing aids is claimed to be the "world's smallest." A second use for the tiny unit has been as a conversation piece for manufacturers' representatives at engineering conventions.

FIG 2—The MS-1 trimmer potentiometer designed for stud mounting. The unit is totally encased in an anodized aluminum housing having an integral threaded portion for mounting. The three connecting leads made of stranded wire with teflon insulation are brought out through the threaded section with an appropriate sealant. The over-all dimensions are ¼ inch diameter x 0.305 inch body length with a 0.190 inch threaded section. The MS-2 trimmer potentiometer is similar to the MS-1 with the exception of the type of mount and method of bringing out the leads. Designed for mounting on printed wiring boards it is equipped with three bare leads brought out in triangular spacing to fit a 0.1 grid. The over-all dimensions are ½ inch diameter x 0.335 inch exclusive of leads.

TINY TRIMMER POTS

16 Units Mount on One Square Inch Surface

Miniature Electronic Components Corp. of Holbrook, Mass., has applied its experience in designing volume controls for the hearing-aid industry to development of two tiny, low-priced, trimmer potentiometers ¼ inch in diameter by 11/32 inch long. The model shown in Fig. 2 is for stud mounting; the other is for lead mounting on printed wiring boards using 0.1 inch grid spacing.

It takes 500 of these units to make up one pound. Twelve of them will readily mount with their centers on a circle of only one inch diameter. You could, therefore, mount twelve units on the rear of a 12-position miniature wafer switch to allow for individual adjustment of each of the circuits associated with the switch. This technique could be used in multimeters, vacuum-tube voltmeters, R-C oscillators, and so forth.

Similarly, since 16 units stack in one square inch of mounting space, you could centralize all the necessary trimmer adjustments behind a small access door in many types of instrumentation and control circuitry.

Wire-wound potentiometers, particularly the trimmer variety, are essentially simple devices. They constitute a length of resistance wire wound in such fashion that it can be contacted in a predictable manner by a wiper actuated by external means. In conventional practice the wire is wound on either a flat card or a cylindrical mandrel which is then fitted in circular form inside a protective covering or base, concentric with a rotary shaft carrying the wiper. A notable exception to this configuration is the rectangular type of trimmer potentiometer in which the wire-wound card is retained in a flat state and the wiper traverses the winding in a translatory manner driven by a lead screw turned by means of a screw driver slot. In the latter type of design many rotations of the adjusting screw are necessary to cover the complete range of the winding giving the illusion of greater "setability," whereas, in fact, this characteristic is governed primarily by the resolution of the winding as determined by the number of turns.

Minelco potentiometers use the conventional wrapped card configuration to obtain a single turn unit in a tiny cylindrical case. Model HA-1 volume control (Fig. 1) developed specifically for the hearing aid industry has been in use for about two years. A cross-section of the unit is shown in Fig. 2. Note that the potentiometer is contained entirely inside the volume con-

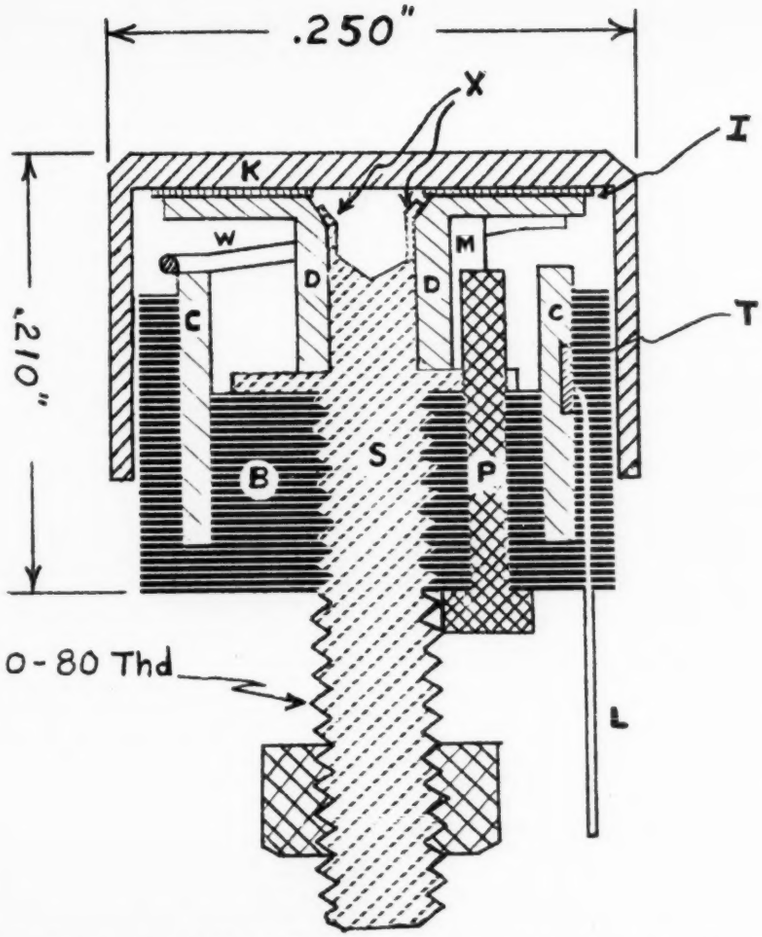


FIG 3—Cross section of Model HA-1 potentiometer. Potentiometer-grade resistance wire is wound on a plastic card (C) and is terminated at each end by a metal tab (T) to which the external lead wires (L) are attached. This construction provides for low resistance end connections at the zero and maximum ends of the control. The card is wrapped inside of a plastic base (B) to which it is cemented. A metal stud (S) is threaded through the center of the base which provides a means of mounting the unit and also provides the external connection to the wiper. A metal disc (D), to which the wiper (W) and a stop bar (M) are attached, is slotted to provide a reliable wiping contact as it is rotated about the stud, and is retained axially on the stud by the crimp shown at (X). The stationary part of the stop mechanism is the pin (P), the head of which also serves as an index pin for mounting. Cemented to the disc separated by a layer of insulation (I), in the knurled knob (K) which is of anodized aluminum and available in a variety of colors. A few dimensions are included on the drawing to indicate the extremely small size of the unit.

trol knob, thus taking no space whatever in the hearing aid—the ultimate in miniaturization.

The new Minelco trimmer potentiometers (Fig. 2) are similar to the volume-control model in internal construction but differ in external appearance and in intended application.

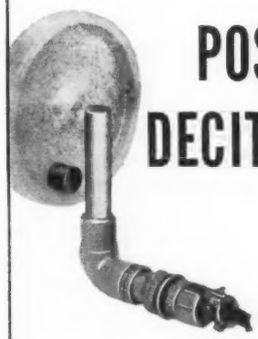
Both are rated at ¼ watt dissipation, have standard resistance values of 500, 1000, 2000, 5000, and 10,000 ohms and linear windings. End resistance and "jump-off" resistance are held to very low values.

Environmental performance of the units is being investigated by several potential users. Although the data are not complete, the following results have been verified:

- Insulation resistance: >100 kilomegohms (three leads to case at 500v d-c)
- Resistance change with temperature cycling: <0.1 percent (5 cycles from 185 degrees F to −67 degrees F)
- Resistance change with vibration <0.25 percent (10 G's from 55 to 2000 cps)
- Change of wiper setting with vibration: none (10 G's from 5 to 2000 cps)
- Noise with vibration: none observable (10 G's from 55 to 2000 cps).

Circle No. 173 on Inquiry Card

MODEL MH-2



POST DECITRON

Magnetic Switch

Post's DECITRON Magnetic Switch is an ideal sensing device for actuating counters, controls, solenoids, relays and many other electrical or electronic circuits.

The Post MH-2 is magnetically operated . . . controlled by the proximity of a magnetic field. A *clean* "*make*" *and* "*break*" is accomplished *at any speed range* from zero to 100 cycles per second.

"Bounce" is eliminated by using a capillary film of mercury. For timing . . . synchronizing . . . or counting . . . specify the dependable, long life — MH-2. Write for literature.

Decitron Electronics Products Division

POST

POST MACHINERY COMPANY

Beverly, Mass.

CIRCLE 5 ON INQUIRY CARD

NEW SEMICONDUCTOR DEVICES

"True Power" Silicon Transistors, Silicon Switches, Solid State Multipliers, Hi-temp Rectifiers

Westinghouse Electric Corporation has opened a new semiconductor plant at Youngswood, Pa. to extend and exploit the semiconductor research and development work of its Research Laboratories in East Pittsburgh, Pa. Both germanium and silicon devices for communications and power applications are manufactured at the new plant. "However," according to D. W. Gunther, manager of the Westinghouse semiconductor department, "emphasis will be on devices for power application because the company's traditional interest is in the power field and because the power field serves as a good base from which to expand into other semiconductor fields."

A recent addition to the plant is a pilot facility to produce ultrapure silicon with less than one part impurity in six billion parts silicon. The silicon material is being manufactured under an agreement with the Siemens Schuckertwerke and Seimens-Halske Companies in Germany, which also permits Westinghouse to license the process in the United States.

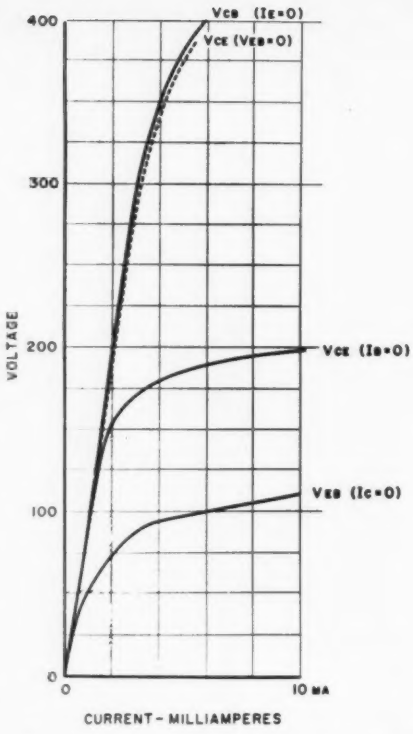
"The availability of this ultrapure silicon," said Mr. Gunther, "together with new device-fabrication techniques has resulted in the development of a new series of 'true power' silicon transistors and silicon switches."

Other new solid state developments to be exploited in the Youngstown plant are: a Hall Generator that puts the Hall effect, discovered in 1879, into practical use, and a rectifier that will operate red hot.

'TRUE POWER' SILICON TRANSISTORS

Two specific types of n-p-n fused-junction transistors have been produced —a 2-5 ampere unit that can handle power up to 1 kw, and a 10-20 ampere unit to handle power up to 3 kw. The low-level theories of transistor operation required revisions in the true power range. New fusion and diffusion methods were developed, together with improved alloy systems, etching procedures and encapsulation techniques to permit the practical fabrication of the basic power transistor design.

2-5 Ampere Unit. The first silicon power transistors produced have emitter-to-collector voltages of from 50 to over 300 volts. Current ratings on these units range from 2 to 5 ampres—based on the current at which current gain is equal to or greater than 10.



Curves showing collector-base, collector-emitter and emitter-base voltages of the Westinghouse 2-5 ampere silicon power transistor in the 300-volt rating. These voltages are claimed to be 3 to 4 times higher than those of other present silicon power transistors.

These high voltages and currents, coupled with very low saturation resistance permit the use of these devices for high-power switching operations with very high efficiencies. For example, as a d-c switch handling 1 kw (200 volts at 5 amperes), the internal dissipation of the units is about 5 watts with a resulting efficiency of 99.5 percent. Reverse leakages of these devices range from 2 to 3 milliamperes.

The silicon transistor can be used at temperatures up to limits imposed by the silicon material itself. This is due to the small case-to-junction temperature rise in switch operation. In the 1-kw switch illustration, this rise is 2.5°C.

10-20 Ampere Unit. Westinghouse has extended the principles and techniques used in developing the 2-5 ampere transistor to produce a device capable of handling up to 3 kw. This represents a great step beyond the 2-5 ampere unit.

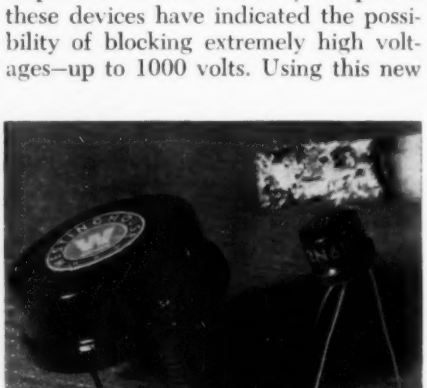
Voltage rating, collector-to-emitter, on present 10-20 ampere units range from 50 to 150 volts. Development work should increase this range to 300 volts. As on the 2-5 ampere devices, the current ratings are specified at a current gain of 10 amperes.

The high current and voltage ratings again represent high-power handling capacies only if the internal dissipation is low. With the increased current ratings, the saturation resistance is decreased and varies from 0.1 to 0.05 ohm. Used as a d-c switch, the 10-20 ampere devices handles 3 kw of power with internal losses of less than 20 watts.

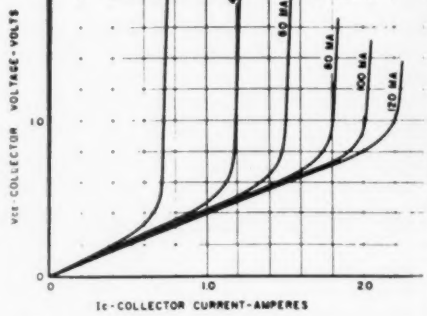
The designers made the encapsulation cases for both the 2-5 amperes and 10-20 ampere silicon power transistors with a screw stud to permit bolting to heat sinks in operation where heat dissipation is set by the operating condition.

SILICON SWITCHES

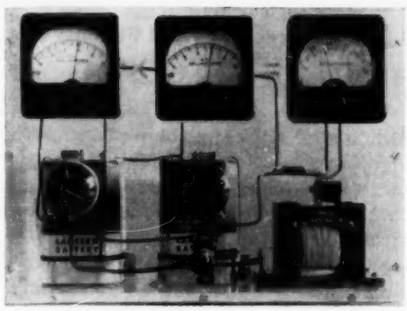
Recognizing the inherent limitations of the transistor structure for high-current switching applications, Westinghouse scientists have developed a silicon switch called a silicon Trinistor triode capable of blocking up to 200 volts and carrying currents up to 10 amperes. Selected laboratory samples of these devices have indicated the possibility of blocking extremely high voltages—up to 1000 volts. Using this new



The basic silicon power transistor is shown compared to a conventional low-power computer transistor.



Curves showing the output characteristics of the 2-5 ampere silicon power transistor in the common emitter connection. Here the saturation resistance at 2 amperes is 0.4 ohms. The current gain at 2 amperes is 20.



Demonstration setup shows the operation of anindium antimonide Hall Generator. The control current being fed to the device (read on the meter at left) is multiplied by the applied magnetic field (read on the meter in center) to produce a Hall voltage (read on the meter at right).

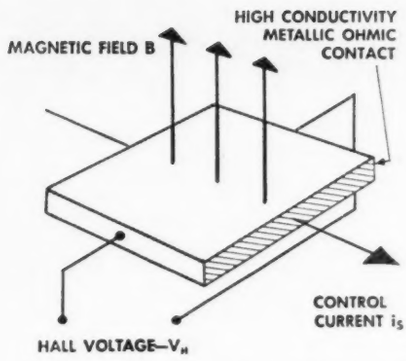


Diagram illustrates the principle of operation of the semiconductor Hall Generator. The control current is at right angles to the magnetic field and produces the Hall voltage.

silicon-switch structure, Westinghouse is investigating the extension of current control to the 100 and 200 ampere range.

In addition to eliminating the current carrying restriction of conventional transistors, another significant advantage of the silicon Trinistor triode over conventional transistors for equivalent ratings and applications is its greatly reduced switching time. The switching time required to go from the On to the Off condition is ten times faster for the switch structure than that of a comparable transistor.

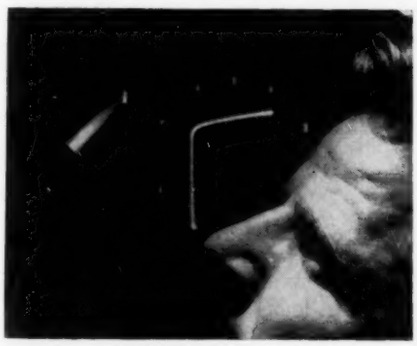
PRACTICAL HALL GENERATOR

Using two semiconductor materials, indium antimonide and indium arsenide, Westinghouse scientists have built a commercially usable and novel circuit element called a Hall Generator.

The Hall Generator is essentially a solid state multiplying device that provides a voltage output proportional to the product of two electrical quantities: (a) the current passing through it; and, (b) the magnetic field perpendicular to it.

This suggests its use as an analog computer element, for example, to multiply directly two electrical quantities. One of these electrical quantities is expressed as a current and the other as a magnetic field.

Output Hall voltages of one-half volt are easily obtained in the Westinghouse device using magnetic fields of 5 kilogaus and control currents of one-half ampere. In addition, the output impedance of these devices can be adjusted from 0.01 to 20 ohms and their maximum frequency response ranges from 10^7 to 10^8 cycles per second.



Backed by an oscilloscope trace which shows its continuous operation, a tiny silicon carbide rectifier (left foreground) is operating while heated red hot with a torch. Developed by scientists at the Westinghouse Materials Engineering Department, the rectifier results from a new method for preparing ultrapure silicon carbide—a common material found in lightning arrestors and grinding wheels.

RECTIFIER OPERATES RED HOT

Westinghouse scientists have developed a semiconductor rectifier that can operate at temperatures above the melting point of metals like magnesium and aluminum. This range—up to 1300°F—is higher than any temperature at which solid state rectifiers have operated before. The "solid state" rectifier is made of silicon carbide, a material long used as a linear resistance element in lightning arrestors and, in its crude form, as an abrasive in grinding wheels.

This rectifier was developed by a team of scientists under the direction of R. E. Davis, manager of solid state engineering department for Westinghouse. The work was done under a contract with the Electronic Components Laboratory of The Wright Air Development Center for a 932°F (500°C) rectifier to use in airborne electrical systems.

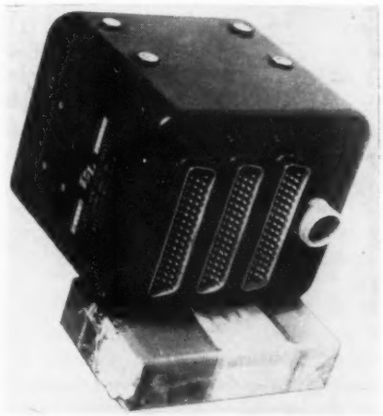
"Our silicon carbide rectifier has progressed considerably beyond the initial stages of its laboratory demonstration," Mr. Davis declared. "While much experimental work remains to be done, the silicon carbide rectifier is no longer a laboratory curiosity."

Essentially, the new high-temperature silicon carbide rectifier consists of a near-perfect crystal of material which has been purposely "doped"—adding a small quantity of an impurity. The location at which the doped and undoped sections of the crystal meet is called the p-n junction: a point across which electrons flow in one direction much better than they do in the opposite direction. The crystal thus acts as a rectifier.

These "grown" junctions of silicon carbide will act as rectifiers capable of withstanding several hundred volts and passing up to 10 amperes of current. Furthermore, in addition to operating when red hot, they possess all the usual advantages of solid state devices including small size, extreme ruggedness, no moving parts and high efficiency.

The grown junction silicon carbide crystals are prepared in a specially designed furnace operating at temperatures higher than 4500°F. The furnace contains an atmosphere of pure helium or argon to prevent contamination of the crystals as they grow inside the furnace. Once the crystals are prepared, they are cut, etched and otherwise treated for fabrication into the tiny rectifiers.

Circle No. 216 on Inquiry Card



A New Commutator Design Concept

A subminiature high-speed sampling switch based on a completely new design concept results in a 50 percent reduction in over-all volume for a given number of circuits. In this unit, the 400-cycle, 115-volt, single-phase drive motor is completely contained inside of the commutating rings. An integral gear box drives 3 poles with 45 BBM contacts at 20 rps. This 3-1/4 x 3-1/4 x 3-1/16 inch hermetically sealed switch weighs approximately 3 lbs and provides both high and low level bounce-free contact operation. The unit has been designed for maintenance-free service over a long life under military environmental conditions. Instrument Development Laboratories, Inc., Attleboro, Massachusetts.

Circle No. 163 on Inquiry Card

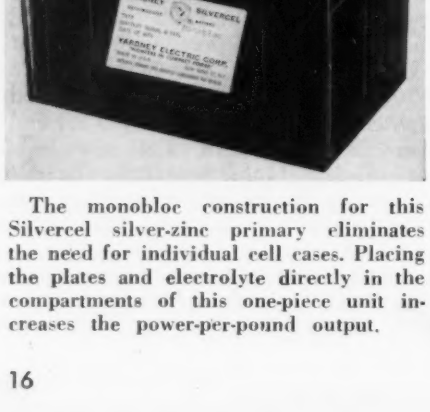
SILVER-ZINC BATTERY

Monoblock Construction and Automatic Activation Further Increase Power

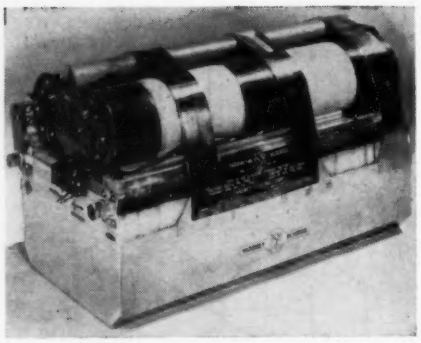
Because of the efficiency of silver-zinc couples, silver-zinc batteries can be made 80 percent smaller and 25 percent lighter than comparable lead-acid units for certain applications. Conversely, where high power outputs are required, they can supply up to six times more power than these conventional batteries on an equal size-weight basis.

Using improved techniques, Yardney Electric Corp. has developed a silver-zinc battery for the Navy's new lightweight torpedo the Mark 43, that has two and a half times the output of earlier silver-zinc models. Two of these techniques are monobloc construction and a new type of automatic activation. Made of lucite, bakelite, nylon or polyethylene, the monobloc is a rugged, lightweight one-piece unit with separate compartments into which are placed the plates and electrolyte. The use of individual cell cases has been eliminated and thus the power-per-pound ratio even more greatly increased. This space and weight saving has made possible primary (one-shot) batteries with separate gas and electrolyte tanks and a new automatic activating system that permits activation and operation of the battery in any position.

With the primary now equivalent to the secondary (rechargeable) battery in power rating, weight, volume and efficiency, this development assumes special importance: complete interchangeability between primaries and secondaries.



The monobloc construction for this Silvercel silver-zinc primary eliminates the need for individual cell cases. Placing the plates and electrolyte directly in the compartments of this one-piece unit increases the power-per-pound output.



Using either an electrical or mechanical device, this Silvercel battery can be activated in split seconds. The activation system provides a lightweight torpedo battery that requires no maintenance, has a long shelf life and can be activated and operated in any position.

To the missile design engineer, for instance, this means that he can use a secondary for exercise and test runs and a primary for tactical end use. Since the end use is a one-shot affair, the primary, with its long shelf life, is a logical choice. Just as logical for proofing out the missile, however, is the secondary, since it can be reused for every test, evaluation and—in case of torpedoes—fleet maneuvers, and its reliability checked.

Yardney engineers report that nineteen missile projects, including the major intercontinental and intermediate-range missiles, now use silver-zinc batteries for power, guidance, control or telemetering, and that their silver-zinc batteries, called Silvercels, have completely surplanted the conventional lead-acid batteries that powered the World War II electric torpedo.

Circle No. 194 on Inquiry Card

WORTH FILING

General Purpose Control Equipment

88 page publication covers complete line of control devices manufactured by General Electric's General Purpose Control Department. Selection charts covering starters through 200 horsepower provide quick selection of the proper starter, heater and pushbutton station for any type enclosure. Illustrated catalog has guide form specifications for easy and accurate designation of controls by distributors, contractors or architectural specifiers.

Two-color publication includes complete product descriptions of motor starters, contactors, relays, solenoids, limit switches, pushbuttons and pilot devices. Catalog also contains prices, features, wiring diagrams, dimensions and application information for each device.

Source: General Electric
Schenectady 5, New York
For your copy: Circle No. 201 on Inquiry Card

WORTH FILING

High Frequency Crystal Filter

Characteristics of a Hycon Eastern Type-22 high frequency Crystal Filter both in the steady state and transient conditions are summarized in a six page memorandum prepared by Columbia University's Department of Electrical Engineering. The excellent pulse response and optimum point for sampling filter output with a pulse input are described.

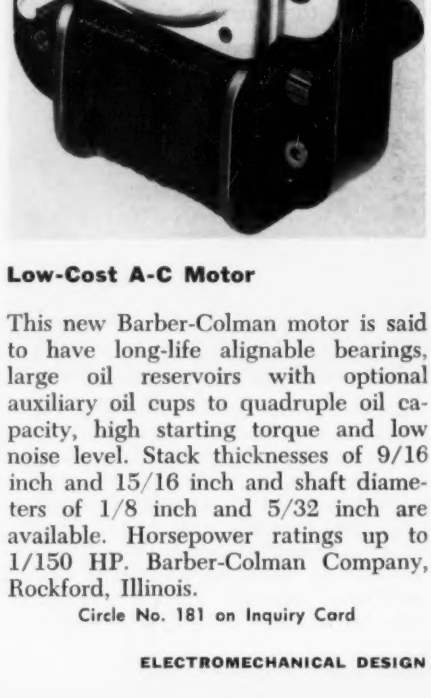
Source: Hycon Eastern, Inc.
Cambridge 42, Mass.
For your copy: Circle No. 199 on Inquiry Card

WORTH FILING

Anechoic Chambers

8 page brochure contains a description of electro-magnetic energy absorbers for VHF, UHF and microwave free-space rooms together with details of construction. Photographs of various types of Anechoic Chamber installations, designed and built exclusively to meet specific requirements of frequency range, shielding, and working conditions are shown, together with equipment used for research and developmental testing.

Source: Emerson & Cuming, Inc.
Canton, Massachusetts
For your copy: Circle No. 198 on Inquiry Card



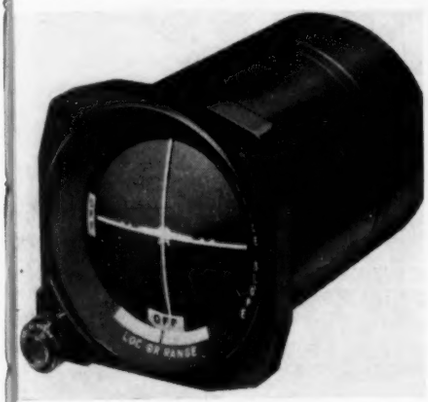
Low-Cost A-C Motor

This new Barber-Colman motor is said to have long-life alignable bearings, large oil reservoirs with optional auxiliary oil cups to quadruple oil capacity, high starting torque and low noise level. Stack thicknesses of 9/16 inch and 15/16 inch and shaft diameters of 1/8 inch and 5/32 inch are available. Horsepower ratings up to 1/150 HP. Barber-Colman Company, Rockford, Illinois.

Circle No. 181 on Inquiry Card

Low Approach Indicator Features Rectilinear Localizer and Glide Slope Display

The rectilinear display design of the Marion Model ID-525 Low Approach Indicator for aircraft results in improved readability, appearance and performance. End-pivoted high torque mechanisms are used for Localizer and Glide Slope indications and two Model MEP-7 short angle mechanisms are used for warning flags. All mechanisms



employ self-shielding internal magnets making compass interference negligible. Hermetically sealed with a tear band, the mechanisms are sub-chassis mounted and can be removed for service by unsoldering the tear band seal. Model ID-525 weighs 24 oz and is interchangeable, mechanically and electrically, with an ID-48. Marion Electrical Instrument Company, Manchester, New Hampshire.

Circle No. 171 on Inquiry Card

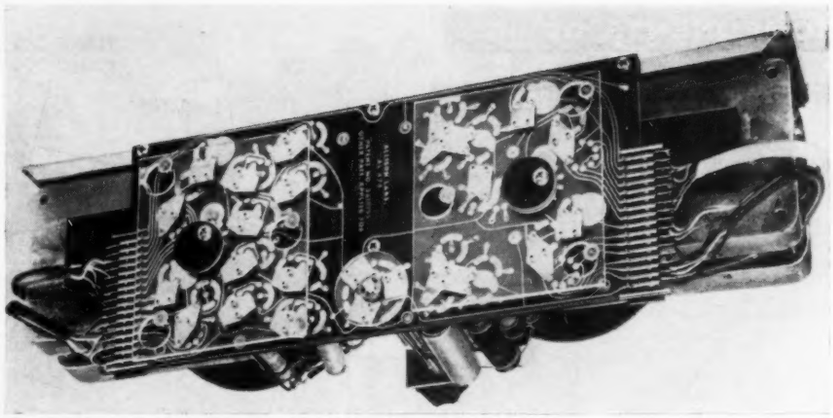
WORTH FILING

Thermistor Probe Assemblies

Nine specially designed thermistor probe assemblies are described in detail in a new 4-page brochure. Each assembly is identified by its most common application. Complete dimensions and mounting arrangements are given. Applications of the probes include air, oil and fuel temperature measurement, surface temperature measurement, and liquid level indication and control. The probes are widely used in missile telemetering circuits and other places where precise and accurate control is demanded. Since each is a completely designed assembly, user's production and testing costs are often lowered. Not only is the probe ready to install, but it can be provided to meet specific design tolerance requirements.

Source: Fenwal Electronics, Inc.
Framingham, Massachusetts

For more information: Circle No. 187 on Card



Switch Integrated into Printed Circuit

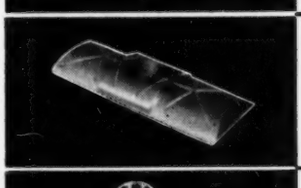
The HEP Switch, a radically new concept in switching, brings the switching operation to the circuit instead of the circuit to the switch. Switching is accomplished by an eccentrically operated scanning plate carrying contacts which engage segmented circles located to suit the circuit requirements. Integrating the switch mechanism into a printed circuit board, provides switching for the circuit without leaving the board. The radical design has reduced soldered connections up to 80 percent and greatly minimized switch wiring errors. The user can have the design flexibility and economy of printed circuits applied to multi-circuit, multi-position switch problems. The designers say that life tests on the HEP Switch indicate a considerably longer life than can be expected from conventional wafer-type switches, and that manufacturers will be able to design products around the new switch that will be smaller and require far fewer components. Hartsall Company, a division of Allison Laboratories, Inc., La-Puente, California.

Circle No. 151 on Inquiry Card

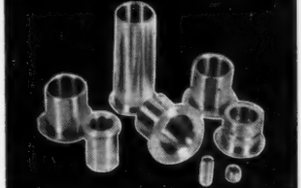
SABECO BRONZE

Industry is cutting costs through use of these SABECO BRONZE PRODUCTS. Countless applications! Check your needs.

SABECO SPLIT THRUST WASHERS
Efficiently take up end play in machine tools, cut repair bills and reduce downtime to a minimum by installing on equipment subjected to bearing thrust loads.



SABECO BRONZE SLIPPER SHOES
Slipper shoes of Sabeco Bronze render outstanding performance and service in many heavy duty applications in any practicable size to customers dimensions and specifications.



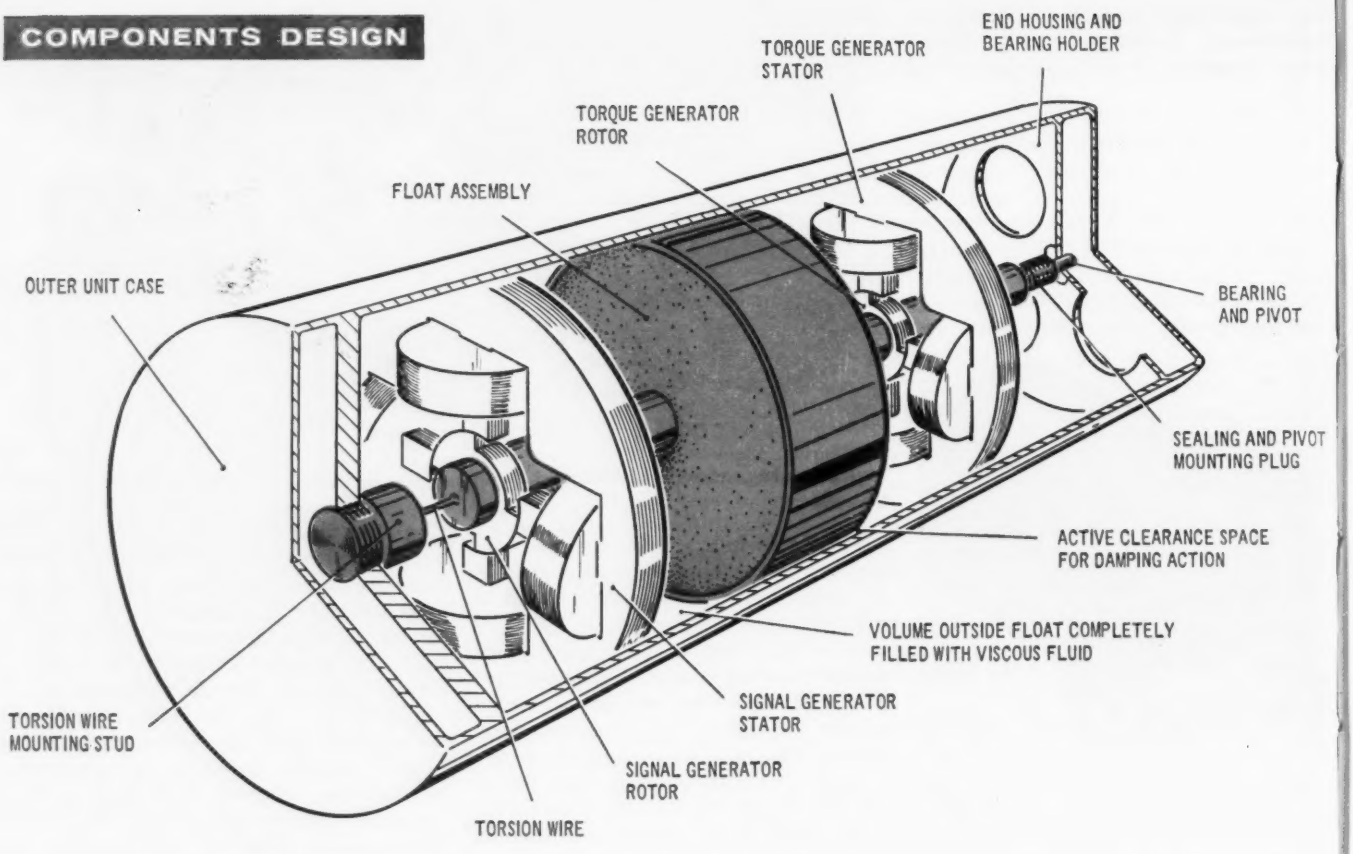
SABECO'S BEAUIDEAL STEEL-BACKED BRONZE BEARINGS
Steel and Sabeco Bronze bonded together forever. The strength of steel combined with the lightness of the bearing's bronze wearing surface makes Beauideal bearings especially adaptable to special applications under extreme bearing load conditions.

Write for Sabeco's bronze brochure giving data, specifications and applications. Dept. E-3

SAGINAW BEARING CO.
821 S. Water
Saginaw, Michigan

SABECO INDUSTRIAL BRONZE BAR STOCK AND CASTINGS
Sabeco is offered in five grades and three forms. Stock bars, solid or cored are carried in stock in a great variety of sizes, available for immediate shipment.

FOR MORE INFORMATION CIRCLE 6 ON INQUIRY CARD



DIFFERENTIAL METER

Gyro Design Techniques Develop Precision Instrument for Monitoring or Controlling Current, Voltage, or Power

The development of inertial guidance components and systems over the past years has contributed a wealth of new design techniques and specialized hardware. Many of these developments are now finding application in other instrumentation and precision-equipment fields. A recent example of this trend is a new electromechanical device that provides extremely accurate indication of deviations in a reference current, voltage or power. For example, when used as a current indicator, the device readily reveals microamp fluctuations in a reference current of the order of 100 milliamps. In closed loop applications, the instrument will control any of these quantities to the same extreme accuracy.

Fig 1—Schematic diagram of DRC's high precision, electromechanical Differential Meter showing how floated-gyro design techniques are employed. The unit consists of a float assembly, floated in a hermetically sealed outer case containing sufficient fluid to provide neutral buoyancy to the float. The float assembly is held by a torsion wire or spring at one end of the cylinder and is supported by a pivot and jewel arrangement at the opposite end. Primary electrical elements are a signal generator to detect the angle of the float with respect to the case and a torque generator in which the reference current, voltage or power signal may be developed. The flotation medium provides viscous damping in addition to neutral buoyancy to the float. In a de-energized condition, with no signal introduced into the generator, the float assembly will assume an angular position within the outer case such that the stress on the torsion wire is zero. This zero torsion position is adjusted so that when the specified reference signal to be monitored is applied to the torque generator the signal generator will indicate null. Outputs from the unit thus indicate deviations from the reference input. The reference can be current, voltage or power depending on the way the generator windings are connected with the reference signal source and the load. For closed loop regulating applications, the signal generator output is fed back to control the reference source.

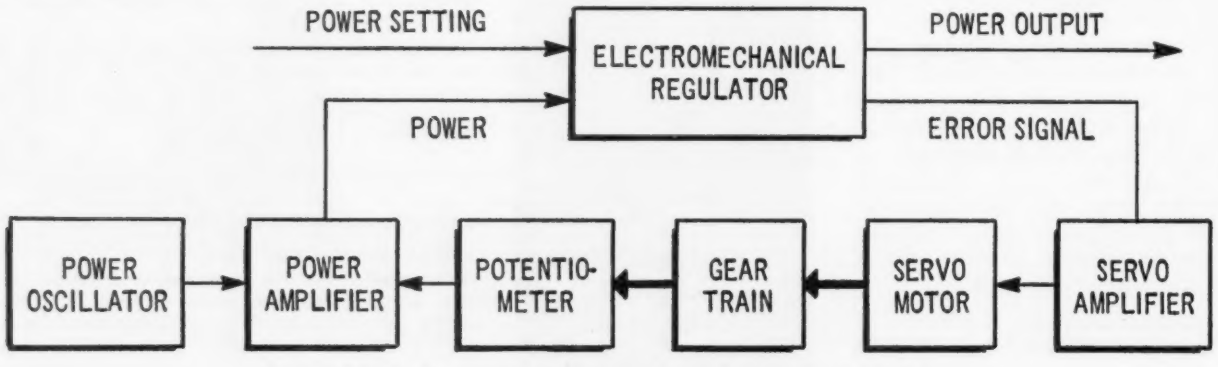
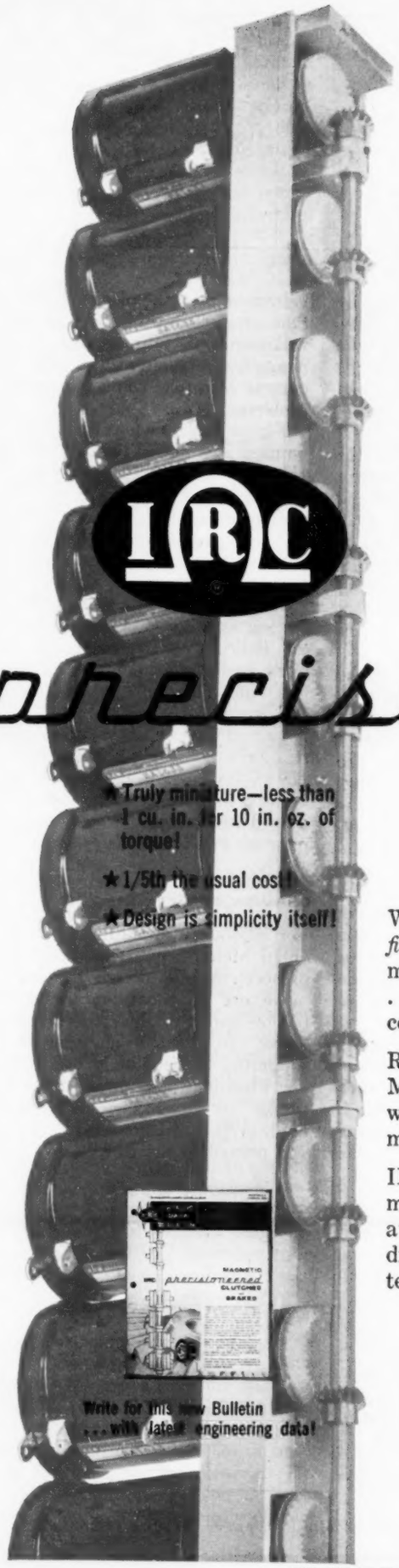


Fig 4—Block diagram of power regulator showing feedback loop.


IRC
★ Truly miniature—less than 1 cu. in. per 10 in. oz. of torque!
★ 1/5th the usual cost!
★ Design is simplicity itself!
Write for this new Bulletin ... with latest engineering data!

MAGNETIC *precisioneered* CLUTCHES and BRAKES

Wherever you design for remote control of a rotating device, think *first* of IRC Magnetic Clutches and Brakes. These precisioneered miniature units can positively cut space, cost and design problems . . . *no matter how you previously did the same job* . . . and at 1/5th the cost of most competitive units!

Replace bulkier, heavier, more complex assemblies with IRC Magnetic Clutches in such equipment as computers, instruments, weighing equipment, speed changers and for other electro-mechanical jobs.

IRC offers you four models for gear and direct-in-line drives in moving coil types. Multi-shaft drives and "custom" units also available. All are D.C. operated. Voltages up to 55. Min. drive torque: 10 in. oz. Max. drag torque: .5 in. oz. Extra high temperature and humidity limits.

IRC

INTERNATIONAL RESISTANCE COMPANY

HYCOR DIVISION

12970 Bradley Ave., Sylmar, California

FOR MORE INFORMATION CIRCLE 7 ON INQUIRY CARD

Design of the device originated out of single-axis floated gyro techniques developed under the direction of Dr. C. S. Draper at the Massachusetts Institute of Technology Instrumentation Laboratory. The first current regulator of this type was designed and constructed by J. P. Andersen, now of Dynamics Research Corp., Woburn, Mass. DRC has developed a general purpose model, called the Differential Meter, illustrated schematically and described in Fig. 1.

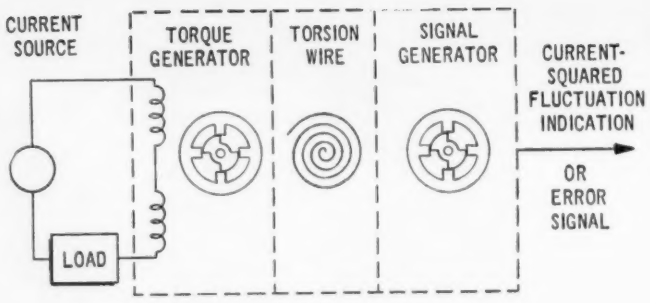


Fig 2—Functional diagram showing connections of Differential Meter used as current deviation indicator.

The accuracy and reliability of this device and the stability of its mechanical elements are inherent in the parent-gyro components. Floated-gyro components offer extreme accuracy in that all sensitive elements are contained in a hermetically sealed can floated in a temperature controlled fluid within an outer cylinder case. Only the differential or unfloated mass of the sensitive element is supported by a jewel and pivot combination. This construction provides gyroscope components with substantially zero friction and immunity from shock and vibration.

So adaptable are gyro and accelerometer design techniques to differential meter designs that experimental meters have been constructed from gyro hardware. However, in most applications, especially those requiring airborne operation, it is necessary to design special components that minimize float-assembly inertia.

APPLICATIONS

Figure 2 shows how the Differential Meter is connected for differential indication of current. The torque generator primary and secondary windings are connected in series with the current source and load. The torque-generator produces a torque about the rotation axis proportional to the square of the reference current. For small changes in reference value, the change in torque is proportional to the change in current. The torque applied to the float assembly by the torque generator is counteracted in the steady state by the torsion wire torque. By appropriately offsetting the torsion wire null from the signal generator null, the device can be adjusted to produce a zero signal for the nominal reference current to be monitored.

Experiments have shown that the Differential Meter responds to torques to one part in 10,000; thus the full potential of the unit is realized for small excursions of the reference. Precision of indication for large excursions depends upon the degree of linearity of the pickoff. It is interesting to note that this device functions as either an a-c or d-c differential current indicator.

Figure 3 shows connections of the Differential Meter for use in differential indication of voltage and of power. The techniques described for current indication apply here except that the load is connected across the windings of the torque generator. Since the torque generator is inherently a current-sensitive microsyn, the voltage indication has a limitation not present in current applications. If the internal impedance of the torque generator changes, more current may flow from the voltage source through the torque generator giving an apparent change in voltage at the output. The degree to which this problem exists is not yet fully explored. It does seem, however, that a settling period will be required while the initial heat transients reach steady state. The fact that the unit is temperature-controlled should minimize this effect. If large excursions in the voltage source take place it is inevitable that some effect on indication accuracy will occur. A torquer that is fundamentally voltage-sensitive rather than current sensitive could eliminate this problem.

Figure 4 shows how the device can be used as a power regulator in single-phase application. The signal generator output is fed back through a servo system to control the power source. Similar systems can be readily developed to regulate current, voltage and three-phase power.

Although the device has wide applications as a general purpose differential indicator or regulator, it is especially useful as an operational and testing unit in inertial guidance activities. It has an important potential in gyro testing. It provides a means of correlation gyro drift with gyro excitation power. As an indicating device it can be used in discovering preload changes caused by changes in clearances, temperature or alignment.

GRAVITY SENSITIVE MODEL

For laboratory applications the Differential Meter may be modified by use of accelerometer design techniques to make use of gravity rather than the torsion spring to bias the signal generator. In this design the float is supported at both ends by pivot-and-jewel bearings, and an unbalanced float similar to an accelerometer float is used. When oriented with the float axis normal to the direction of gravity

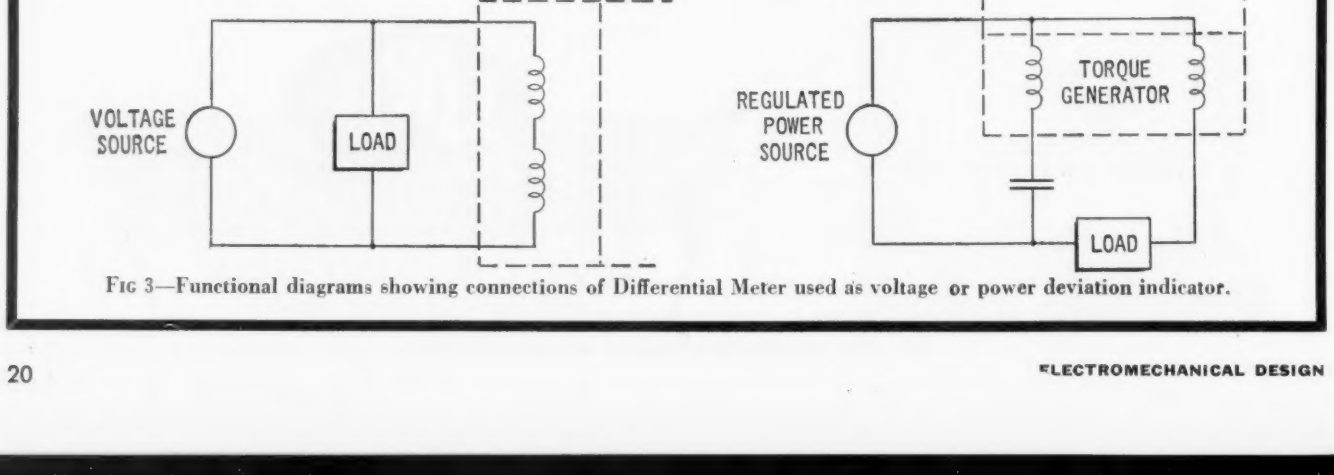
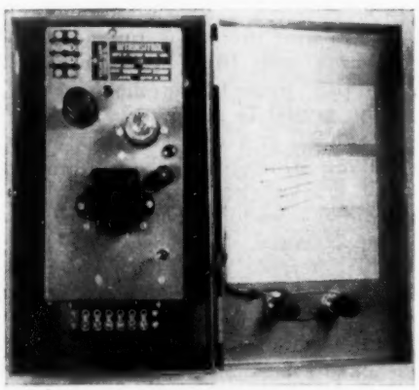


Fig 3—Functional diagrams showing connections of Differential Meter used as voltage or power deviation indicator.

and so that the signal generator output is zero, the meter is in zero reference position. Rotating the case through some angle about the float axis moves the signal generator output off the null in proportion to this angle. Simple adjustment determines the proper angular displacement of the meter case to make the signal generator output correspond to the nominal reference quantity to be monitored.

The advantages of this instrument are the ease with which it can be adjusted to a given reference input and the greater accuracy resulting from use of gravitational force rather than torsion spring force which is subject to hysteresis effects.

Circle No. 188 on Inquiry Card



Exposed Contact Explosion Proof Switching

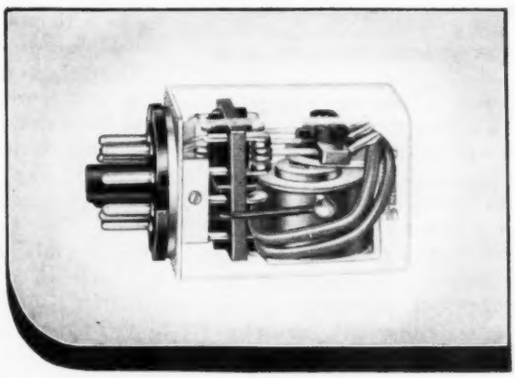
A newly designed switching device permits exposed contact switches to be operated in Class I hazardous atmospheres. Brookdale Engineering & Services Co. engineers point out that this unit was designed for exposed contact switching in atmospheres such as acetylene, hydrogen, ethyl ether, gasoline, naptha, acetone, metal dusts, coal and coke dusts, grain dusts, combustible fibers and other dangerous fluids or gases. Designated intrinsic, the unit is designed so that the electrical spark energy available to the remote exposed actuating switch contacts in the hazardous area is below the minimum required to ignite any of the materials mentioned above. Normally the controller is located in a non-hazardous area, sealed from vapor communication with the hazardous area. Switching in the explosive atmosphere can be of any type and can be exposed to the explosive mixture. The wires from the sealed-off barrier consist of insulated wire enclosed in a metal shield either rigid or flexible. Controlled distances of up to 1,000 feet or more are possible. This packaged remote control system is 7 x 12 x 6½ inches with an easily changeable plug-in control chassis.

Circle No. 169 on Inquiry Card

EVERYTHING UNDER CONTROL

GUARDIAN®

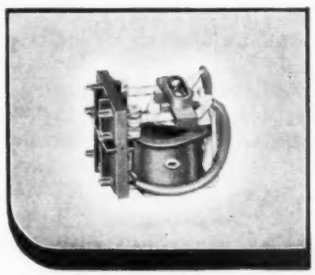
FEATURES THE NEW



Series 1210 Relay IN UNIQUE PLASTIC CASE

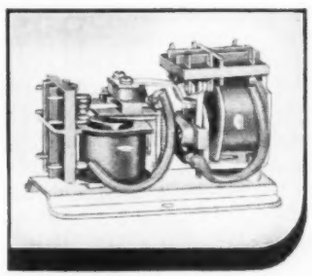
Series 1210 with Dust-Tight Case

This popular small-size medium power relay in its new type special plastic enclosure provides *dust-free* efficient operation for a variety of applications. Resists temperatures up to 200° F., is unaffected by weather. Case is transparent and possesses high impact strength. Relay is available enclosed with 8-pin octal plug for D.P.D.T., and 11-pin octal plug for 3 P.D.T. Contacts are rated at 8 amperes, 60 cycles, 115 volts non-inductive load. Size: $2\frac{23}{32}$" x $1\frac{3}{8}$" x $1\frac{3}{8}$". Arrange for a production sample.



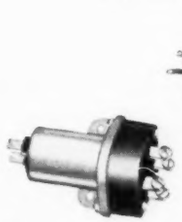
Series 1200 Relay

A small size highly efficient medium power relay rated at 8 amperes, 60 cycles, 115 volts non-inductive load. Heavy solder lug type terminals are molded in phenolic block with barriers for over-surface insulation. Built to meet U/L specifications. Size: $1\frac{5}{8}$"x1"x$1\frac{1}{4}$".

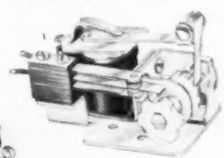


1200/1200 Interlock

Used to maintain circuits continuously without coil power consumption. Unit is electrically pulse operated with mechanical hold and electrical release. Contacts rated at 8 amperes, 60 cycles, 115 volts, non-inductive load. Size: $2\frac{1}{8}$"x $1\frac{13}{16}$"x$1\frac{3}{4}$".

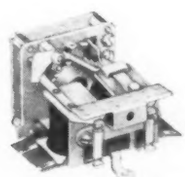


Guardian Powerloid



Guardian Impulse Ratchet

Guardian Power Relay



Guardian M.E.R. Stepper

Write for details

IN STOCK at Your Nearby Guardian Franchised Industrial Distributor

GUARDIAN ELECTRIC

MANUFACTURING COMPANY

1641-D W. WALNUT STREET, CHICAGO 12, ILLINOIS

FOR MORE INFORMATION CIRCLE 8 ON INQUIRY CARD

STAFF COLUMNIST

David Bandel
Associate Technical Director,
TRACERLAB, INC.

NUCLEAR BATTERIES

The prospect of direct conversion of nuclear energy to electricity hangs in front of us like the carrot before the donkey. We have the picture of an increasing quantity of radioactive fission products from nuclear piles becoming available and the challenge to convert this potentially useful by-product material from a king-size disposal headache to something of real value. One approach to this problem is the nuclear battery, which would convert the energy available from radioisotopes into electricity in the same way that chemical energy is converted into electrical energy in our present day batteries. There are, however, some basic facts of life about radiation energy that must be considered in attacking this problem. The chief consideration is the small quantity of actual radiation power that is involved even in what is considered to be a large radioactive source. For instance, the radiation power of a 1000-curie beta source, such as strontium 90, calculates out to be about 1.2 watts. In practice 100 millicuries would be the useful limit of radioactivity that could be handled from the point of view of safety. Nuclear battery power is definitely in the sub-flea power class unless some practical means of current multiplication can be devised.

The first nuclear battery based on beta current was demonstrated by Moseley in 1913 (Fig. 1). The principle is quite simple. A beta emitter is placed on an electrode in a vacuum. Emission of beta particles leaves a positive charge on the electrode and produces a stream of electrons capable of conducting the current as the electrons pass to the collector electrode. Potentials of 150 Kv were obtained before internal flashover discharged the generator. Improvements in the Moseley generator by Linder (1) in 1952 produced a potential of 365 Kv. Attainment of the high potential is not instantaneous but is a function of time similar to the slow charging of a capacitor. In 1953 Coleman (2) developed a nuclear battery using polystyrene as the insulator in place of the vacuum of Moseley and Linder (Fig. 2). Coleman found that polystyrene was capable of withstanding the drastic reduction in electrical resistivity and physical degradation caused by ionizing radiation passing through organic dielectrics. This property of polystyrene made possible the use of a solid dielectric in place of a vacuum. A practical solid dielectric battery based on this design was developed capable of producing a maximum charging voltage of 7,000 after two weeks with an output current of 40 μμa at zero voltage in a space of only 1 inch³.

The beta current type cell described above is limited to very low currents per millicurie of activity. Batteries have been developed using current multiplication schemes. One such device, the junction type cell (3) is illustrated in Fig. 3. The beta particle from the strontium-yttrium-90 source produces 20,000 electrons in passing through the silicon. This electron avalance process is quite efficient, absorbing about 3 electron volts from the beta particle for each electron-hole pair formed. Threshold level of radiation damage to the crystal is rather low, about 0.2 Mev, so that the cell will fail in a few weeks because of changes in the crystalline structure of the silicon. The emf is also low, about 0.2 volt per junction, so that a large number of cells would have to be placed in series to develop any appreciable potential.

The contact potential difference cell, Fig. 4, described by Thomas (4) has characteristics intermediate between the pure beta current and junction diode cells. Difference in work functions of the electrodes establishes a potential difference. The radioactive source produces beta particles which, in turn, produce ion pairs, by collision with the fill gas. Since each ion pair produced requires approximately 30 electron volts of energy, the number of ion pairs theoretically possible depends upon the energy of the beta particle. For tritium with an average beta particle energy of 0.006 Mev, theoretical maximum current multiplication factor has been found to be close to 100. Prototype contact potential difference batteries have been built with 1.7 volts per cell and a short circuit current of 700 μμa.

Several other types of cells using radioactive isotopes have been proposed. Thermal energy of nuclear disintegration can be converted into an electric current via thermopiles. Efficiency of this process is about 0.2 percent. Light from radioactivated phosphors can be used to excite a photovoltaic cell or photojunction. In general, conver-

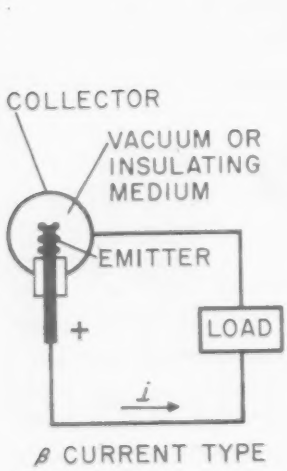


FIG 1

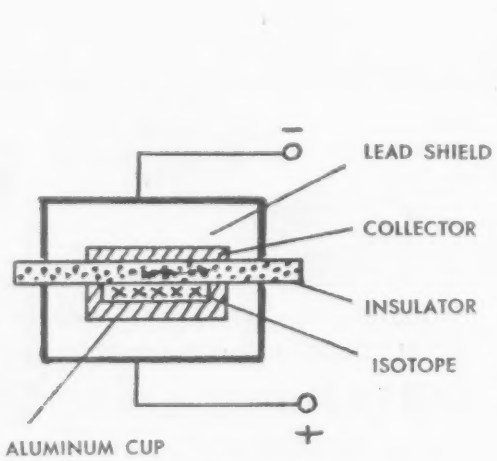


FIG 2

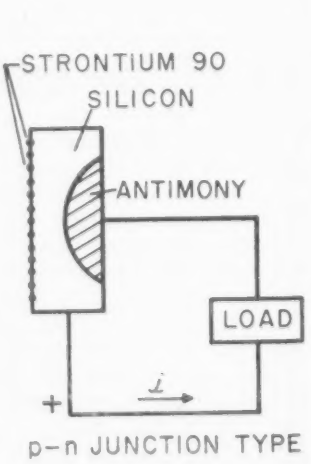


FIG 3

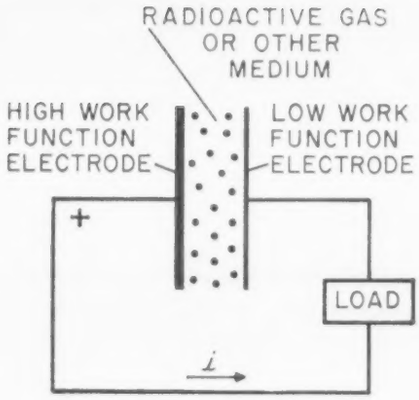


FIG 4

sion efficiency for these systems appears to be too low for practical consideration. A secondary emission type of cell has been under investigation by the Signal Corps. In this cell, a sensitive surface is bombarded by beta particles from a radioactive source on the sensitive surface. The secondary electrons ejected from the sensitive surface are collected on an insensitive surface. Some current multiplication is obtained. Since maximum energy of the secondary electrons is around 20 volts, this would be the approximate open circuit voltage of the cell.

Conversion efficiency of radioactive energy to electrical energy delivered to a matched load in these cells is low, 0.1-2.0 percent, except for the beta current type operating at high voltage. It does not appear likely at present that the efficiency will be improved much above the upper limit of 2 percent.

Cost of radioactivity for nuclear batteries has been calculated by Thomas (5). It is computed per watt hour at 2 percent conversion efficiency with the power delivered to a matched load for one half-life. Results of Thomas' calculation are summarized in the table below.

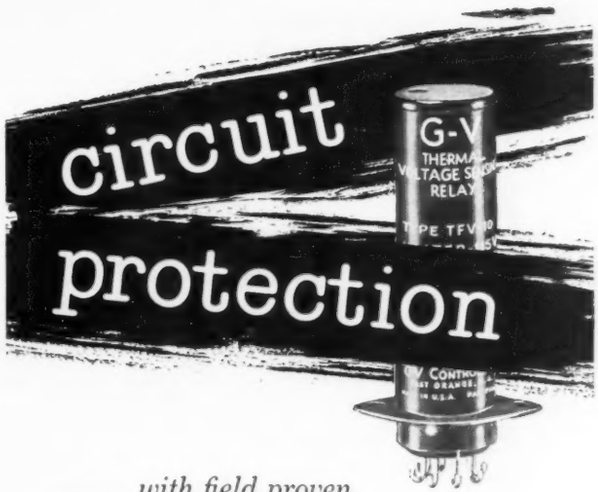
Isotope	*Half-Life*	*Isotope Cost Per Curie*	*Isotope Cost per Microwatt Radioactive Power (Before Decay)*	*Cost Per Watt Hour*
Polonium 210	138 days	$2,500	$0.08	$1700
Krypton 85	10.3 yrs.	15	0.012	9
Tortium	12.4 yrs.	2	0.06	40
Radium D	22 yrs.	35,000	1.05	375
Strontium 90	25 yrs.	500	0.09	30
Nickel 63	85 yrs.	45,000	20.85	19400
Carbon 14	5570 yrs.	22,000	71.80	103

For general comparison, a type-D flashlight cell will deliver about 2½ watt hours at a cost of 15 cents or 6 cents per watt hour. On a cost basis, nuclear batteries are certainly way out in left field.

There are applications where the nuclear battery might well be worth the high cost. Shelf life if not an important factor, as it is in chemical batteries. Power delivered by nuclear batteries can be stored in low loss capacitors and the energy stored in the capacitor used for one-shot devices such as trigger circuits.

A neon bulb relaxation oscillator has been powered by a nuclear battery.

(1) *E. G. Linder, S. M. Christian, J. Appl. Phys. 23, 1213 (1952)*
(2) *J. H. Coleman, Nucleonics 11, No. 12, 42 (1953)*
(3) *P. Rappaport, Phys. Rev. 93, 246 (1954)*
(4) *A. Thomas, Eighth Amer. Battery Res. & Dev. Conf., Signal Corps Eng. Labs., Fort Monmouth, N. J. (1954)*
(5) *A. Thomas, Nucleonics 13, No. 11, 130 (1955)*



with field proven

G-V THERMAL SENSING RELAYS

G-V Sensing Relays operate contacts when current or voltage to their heaters exceeds or drops below the operating point. They can be selected with a response rate paralleling the action of the equipment. These relays operate quickly on heavy changes but tolerate slight changes until they become dangerous.

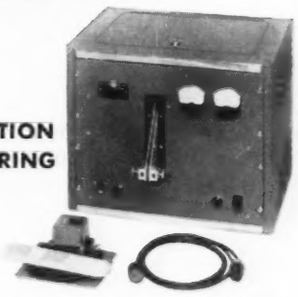
Meets military requirements

Write for Engineering Assistance and complete technical Data. Ask for Publication 70.

G-V CONTROLS INC.
58 Hollywood Plaza, East Orange, N.J.

CIRCLE 9 ON INQUIRY CARD

marion
advancement in instrument design



INDUCTION SOLDERING UNIT

Model PM 1

FOR SMALL PARTS AND ASSEMBLIES

Simplifies, improves and speeds up component production. Provides local heat to otherwise inaccessible spots. Safe and simple. Max. power input 775 watts, 100 watts standby; 115 volts, 60 cycles. 15¾" x 21½" x 15". 150 lbs. Bulletin on request. Marion Electrical Instrument Co., Manchester, N. H., U. S. A.

Copyright © 1958, Marion

marion meters
"WHERE ELECTRONICS MEETS THE EYE"

CIRCLE 10 ON INQUIRY CARD

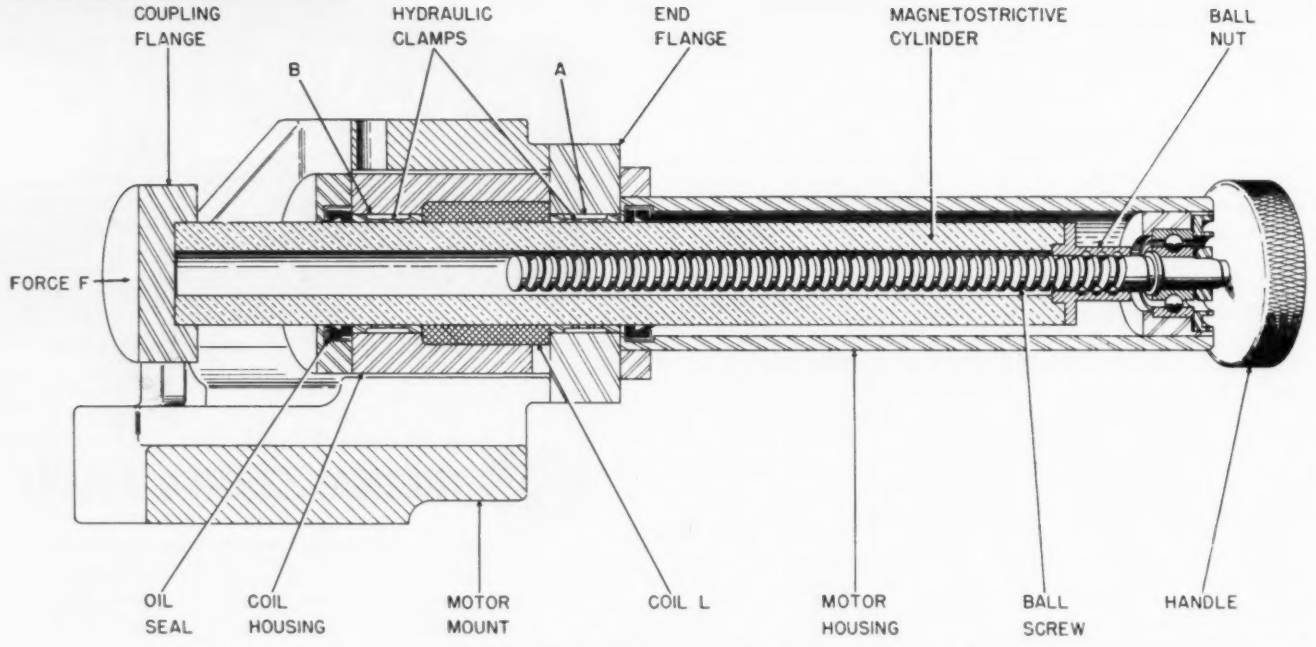


FIG 1—Cross-section of one inchworm motor design shows how a magnetostrictive nickel rod is supported in a pair of co-axial clamps. A and B. These clamps are spaced to provide a maximum step size. Coil L generates a magnetic field in the rod. For movement to the left the system is sequenced so that clamp A is opened, the coil is energized shrinking the nickel bar in the magnetic field, clamp A is closed, clamp B is opened, the coil is de-energized allowing the prestressed nickel bar to expand against the force F and, finally, clamp B is again closed leaving both clamps on in the rest position. A similar sequence in reverse order causes movement in the opposite direction.

INCHWORM MOTOR

Magnetostrictive Forces Actuate Linear Feed Mechanism

The inchworm motor, a linear actuator developed by Airborne Instruments Laboratory of Mineola, New York, is a powerful feed mechanism that is accurately controllable in microinches. The design employs the magnetostriction phenomenon—the change in dimension that occurs in certain materials when they are placed in a magnetic field. For example, a properly heat-treated nickel rod can produce a magnetostrictive change up to 0.00003 inch per axial inch of rod length. The total amount of motion obtained is proportional to the magnetic field strength up to the point of saturation and, inversely, to the resistive load in accordance with Hook's law—the proportionality of stress to strain.

In the inchworm design, the armature of the motor shrinks under the influence of an electromagnetic field, snapping back to the original size when the magnetic field is de-energized. A pair of clamps act together with the armature to convert the expansion and contraction into forward or backward motion reversing on demand without backlash.

Because the inchworm motor concept can control the movement of large forces from 0.000005 to 0.0001 inch, a logical application is in the machine tool field replacing lead screws in centerless grinders for precisely finished

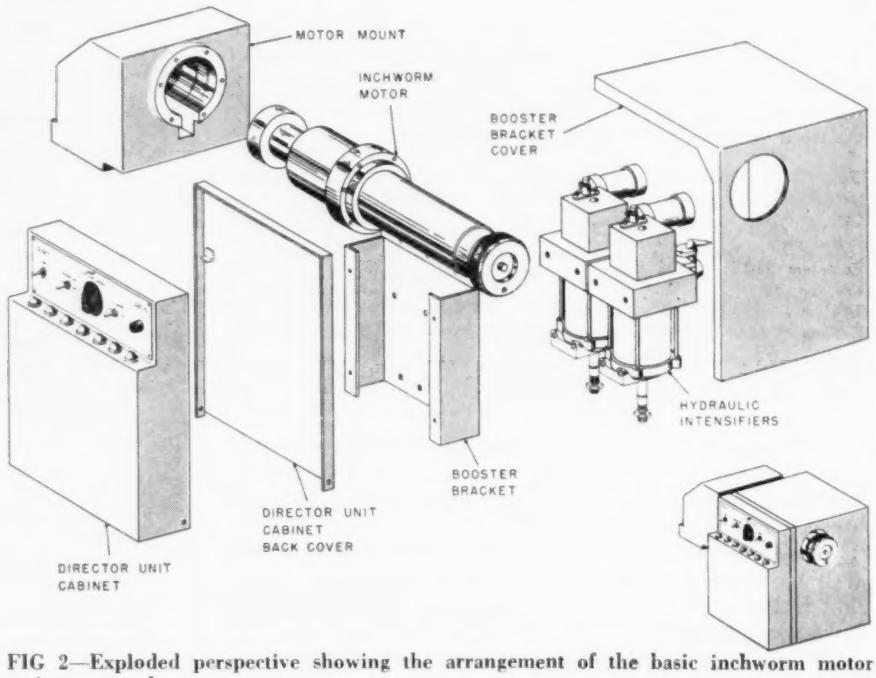


FIG 2—Exploded perspective showing the arrangement of the basic inchworm motor and its controls.

machine components. It recently found its first large-scale application in this field when the Torrington Company of Torrington, Conn., applied the inchworm motor to equipment in their needle bearing plant.

Torrington manufactures precision anti-friction bearings for use in automobiles, airplanes, precision instruments, electronic computers and other precise applications. Maintaining close tolerance specifications on a high-speed assembly line operation presents their production engineers with many problems, one of which involves the matter of human fatigue, cumulative as the

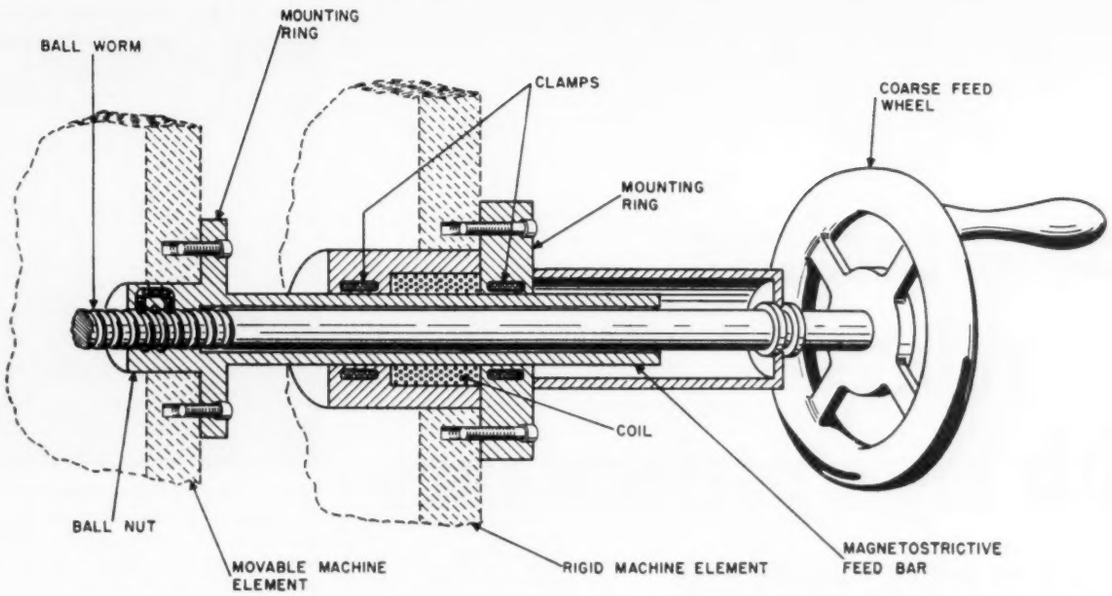


FIG 4—Functional schematic of inchworm motor set up in conjunction with a coarse feed wheel.

work day progresses.

Torrington's needle bearings are ground to size and finish on centerless grinders. Each needle bearing is carried on a work rest and positioned between two rotating wheels, a regulating wheel that controls the rotation of the part and a grinding wheel which does the actual grinding.

The distance between the two wheels determines the size of the finished part. Adjustments in part size are made by moving the regulating wheel toward or away from the grinding wheel, depending upon whether part size is to be decreased or increased. The conventional method of moving the regulating wheel and thus controlling the size of the finished part is for the machine operator to rotate a hand wheel on the end of a lead screw. As the lead screw rotates, the regulating wheel slides forward or backward, depending upon the direction the lead screw is rotated and by an amount determined by how far it is turned.

When the regulating wheel slide is stationary, the force that must be exerted to start its movement is greater than the the force required to continue the movement—the force necessary to overcome the inertia of the system. During this time, the lead screw winds up somewhat like a spring until sufficient force has been accumulated to overcome the static friction of the system. Then, the slide lurches forward, frequently by an amount greater than the desired correction.

The inchworm motor overcomes this disadvantage of the lead screw method of controlling grinders. The magnetostriction in the inchworm operates in juxtaposition with a pair of hydromechanical clamps. Motion is produced by shrinking the magnetostrictive armature while the clamp at one end is locked and the one at the other end unlocked. This allows one end of the armature to move. The opposite clamp is then locked while the first one is unlocked and the armature is expanded by removing the magnetic field. The result is a net motion of the armature in the direction along its length. Motion may be either forward or backward depending upon the order in which the clamps are locked and unlocked together with the timing of the current through the magnetic coil that sur-

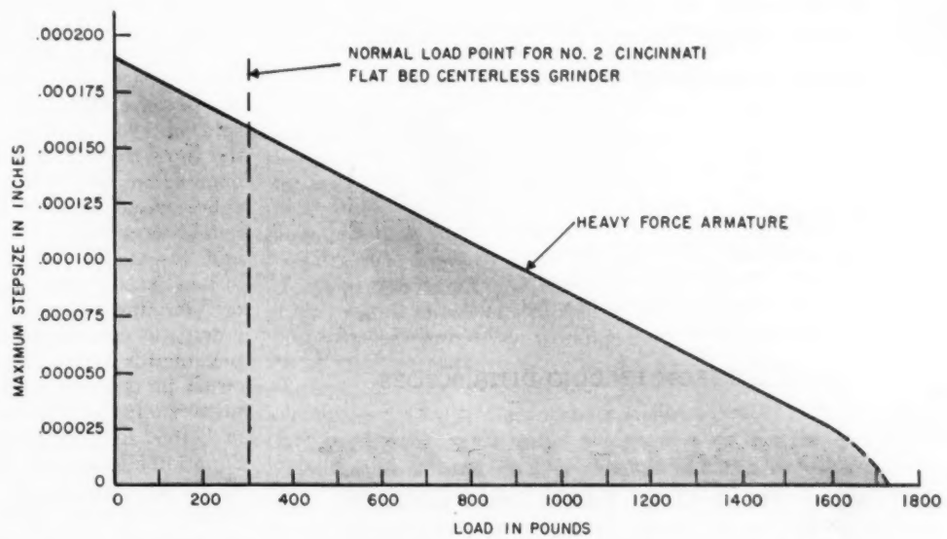
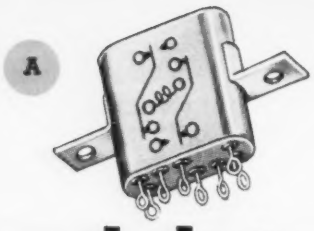
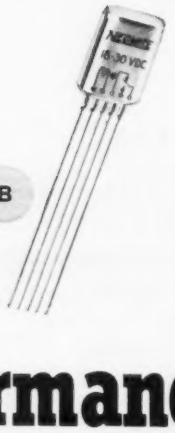
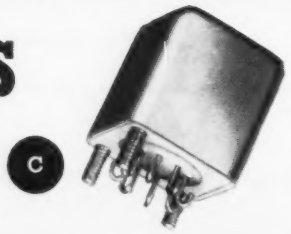


FIG 5—Inchworm motor load characteristics step size versus load.



sub-miniature relays with high performance characteristics





A
MV
crystal can size

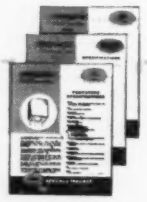
Vibration: 10 to 34 cycles per second at maximum excursions of .4". 34 to 2000 CPS 20G's acceleration.
Weight: 0.45 ounce (max.)
Size: .875" high x .797" wide x .359" thick max.
Pull-in Power: 250 milliwatts at 25°C.
Contact Rating: 2 Amps resistive at 32 VDC or 115 VAC.

B
NM
the famous NEOMITE

Vibration: 10 G to 500 cps.
Weight: .09 oz.
Size: H: .530" ±.015; W: .392" ±.010"; D: .196" ±.010"; Lead length: 1.5" ±.0625".
Pull-in Power: 100 Milliwatts.
Contact Rating: .25 Amp at 28 VDC resistive load.

C
...and announcing the brand-new
VG

Vibration: Low Frequency—10 G's, 10-55 CPS (total max. excursion, .06").
High Frequency—15 G's, 55-2,000 CPS.
Weight: 1.5 ozs., approximately.
Size: 7/8" ±1/64" sq. x 1 1/8" ±1/64".
Pull-in Power: 340 Milliwatts at 25°C.
Contact Rating: 5 Amps at 26.5 VDC or 115 VAC, 60 Cycles resistive load.
Shock: 100 G's, per MIL-R-5757C, Shock Test II.



Advance Sub-miniature Relays are ideal for critical aircraft and missile applications. They feature small size, low weight, and high-precision performance. All have low power requirements.

Write today for complete data sheets.

AVAILABLE FROM LEADING DISTRIBUTORS

ADVANCE RELAYS

ADVANCE RELAYS
A PRODUCT OF ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
Dept. E, 2435 N. Naomi St., Burbank, California

FOR MORE INFORMATION CIRCLE 11 ON INQUIRY CARD

continued from page 25

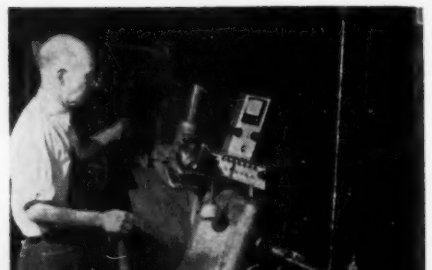


FIG 3—Inchworm installation at Torrington needle bearing plant controls centerless grinding operations to consistent accuracy within millionths of an inch. Linear actuator replaces the lead screw in mechanisms requiring micro-inch dimensional controls.

rounds the magnetostrictive material. The over-all effect is very similar to that by which the inchworm's familiar green namesake progresses along a tree branch, gripping the branch with its forefeet, hunching its body forward then gripping with the hind feet.

To make the operation completely automatic, designers at Airborne Instruments Laboratory, Inc., added electronic gaging equipment capable of determining when the wheel adjustment was necessary and transmitting the instructions to the control mechanism. This system is now a standard unit for applications of this type. Demonstration installations of the inchworm motor have consistently reproduced an accuracy of ±0.000005 inch under machine load conditions requiring a break-loose force of 300 pounds and a sliding force of about 220 pounds. This type of accuracy is based on maintaining a very rigid connection between the two moving parts, one of which is stationary because there are no lead screws, split nuts or bearings in the part of the force transmission. In addition, the elimination of the torsional factor in conventional systems permits the system to be extremely rigid, yet reversible and essentially free of backlash and lost motions encountered in oscillatory or vibrating systems. The inchworm automatic control system has made it possible for Torrington to produce precision parts to an accuracy that is approximately 50 millionths of an inch or better. According to John S. Miller, Superintendent of the Torrington Roller Plant, an improvement in size control has been achieved without any sacrifice in the speed at which parts are ground.

Circle No. 157 on Inquiry Card

THERMO-ELECTRON ENGINE

Converts Atomic Heat Directly to Electricity

If two metal plates are placed side by side and one is made hotter than the other, electrons jump from the hot plate to the cold. This principle has been applied to convert heat directly into electric power without use of any moving mechanical parts and with a thermal efficiency of about 12 percent. The inventors believe efficiencies of about 30 percent are possible.

The invention has been under development over the past five years by George N. Hatsopulos, Assistant Professor, and Joseph Kaye, Professor, in the Department of Mechanical Engineering at Massachusetts Institute of Technology.

Thus far, the process has been conducted inside a large vacuum tube only. "But now that we have a working model," says Professor Kaye, "it appears that a relatively simple electron heat engine can be built using ordinary or nuclear fuels to yield from 5000 to 15,000 watts per cubic foot of total plant volume with a probable thermal efficiency of better than 10 percent. On the basis of efficiency alone, the machine should be more than competitive in the small power plant field." "Isotope heating," Professor Hatsopulos says, "is a very promising possibility for the near future. Isotopes made radioactive can give back this energy in the form of heat. Radioactive isotopes with a long life could readily be used as a heat source for the new engines."

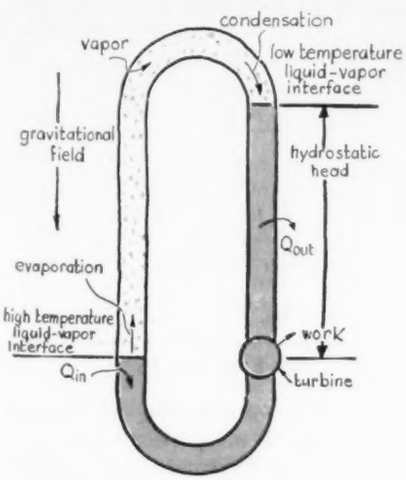


Fig. 2—Steam cycle analog of the Thermo-Electron Engine. The high temperature liquid-vapor interface is similar to the hot plate of the Thermo-Electron Engine while the low temperature liquid-vapor interlace is similar to the cold plate. The difference in height of the two interfaces is analogous to the difference in potential of the two plates.

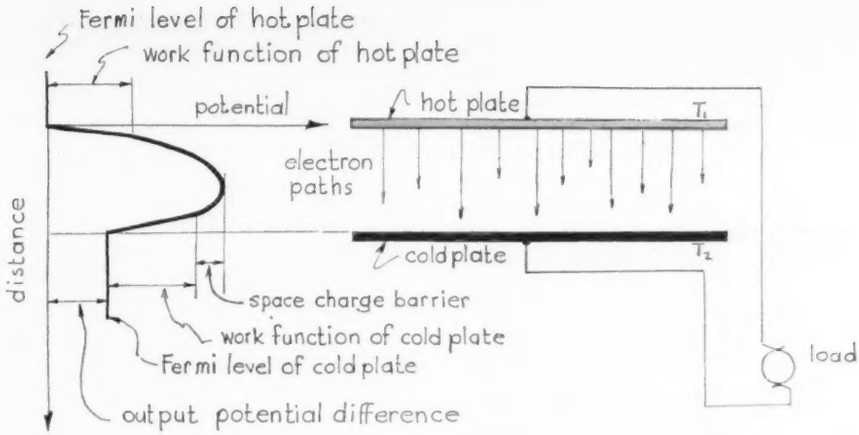


Fig. 1—Schematic operation of the Thermo-Electron Engine. Electrons are boiled out of the hotplate and migrate toward the coldplate where they are absorbed. They return through the external load to complete the circuit. The potential barrier to this flow is shown at the left, where the work functions of the hot and cold plates and the potential due to space charge are plotted.

Prof. Kaye adjusts distance between hot and cold plates of MIT's lab model of Thermo-Electron Engine while Prof. Hatsopulos, seated at the control panel, reads the engine's power output.

The MIT device is called a thermo-electron engine because basically it is a heat engine that uses electrons instead of steam or some other working fluid. In all heat engines, working fluid goes through a cycle in which heat is exchanged between two or more temperature reservoirs and useful work is delivered to the outside as a result. In most conventional steam power plants, for example, steam is used as the working fluid of the heat engine. It receives heat from hot combustion gases, delivers electrical work through a turbine-generator combination, and rejects heat to cooling water in the condenser.

In the Thermo-Electron Engine the working fluid is composed of electrons. But the cycle of events is similar to that for steam in a conventional power plant. It works as follows: free electrons, found in most metals, are forced to leave a suitable metal by heating it to a high temperature, such as 2000°F. The heating creates a stream of "hot" electrons, some of which possess sufficient energy to overcome a potential barrier or an applied voltage. This barrier tends to slow down these electrons and so provides a means of extracting directly useful energy

in the form of electrical output.

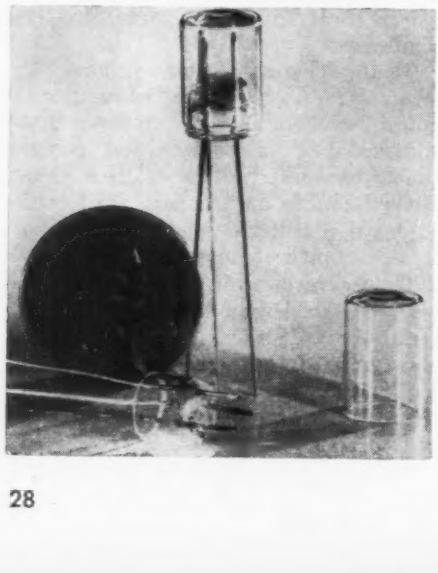
The electrons which overcome this applied voltage are collected in another metal and heat is rejected from this metal to the surroundings. Useful electrical output is obtained by connecting the hot metallic surface externally through a load to the cold collecting surface. Thus the electron gas goes through the typical heat engine cycle of receiving heat at a high temperature and rejecting at at a lower. But unlike the typical system it achieves useful work output directly with no moving parts.

Professors Hatsopulos and Kaye are also investigating another thermo-electron engine which uses crossed electric and magnetic fields to control the flow of electrons. They predict that this device may attain even higher efficiencies than their present model. They point out however that a lot of development work lies ahead before thermo-electron engines can be put into commercial operation. This development is being undertaken by the Thermo-Electron Engineering Corporation of Cambridge, a research organization established about two years ago to work in the field of energy conversion devices.

Glass Transistor Enclosure

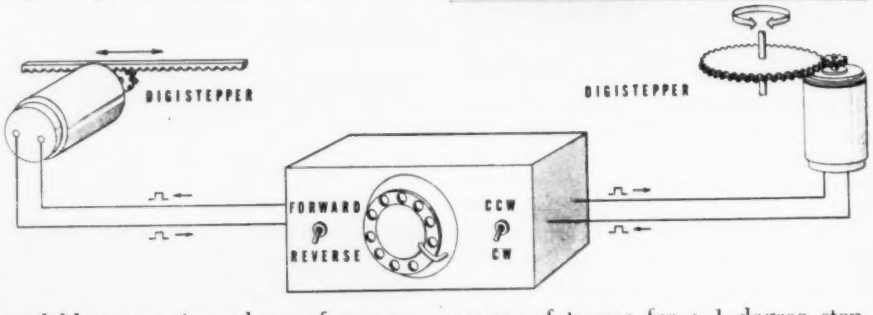
A two-piece all-glass transistor enclosure is being produced by means of a new, close-control electric sealing process. The base and envelope are hermetically sealed at 1000°C while temperature near the semiconductor, less than ¼ inch away, is kept below 150°C. Sealing is done in approximately 10 seconds. Both base and envelope of the 200 mil lead circle-enclosure are made of strong, thin-walled, precision glass tubing of high purity. Current production of the new transistor case is limited to the 200 mil lead circle type for low power units. Other sizes will be available in the near future. Corning Glass Works, Corning, New York.

Circle No. 177 on Inquiry Card

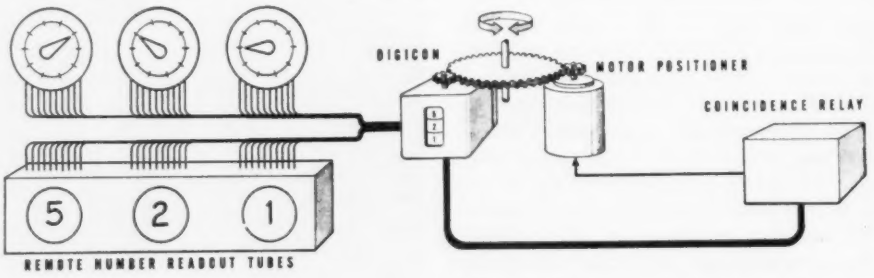


Actuation Direct From Computer

This unique digital actuator motor is a new tool for use in digital control of gyros, magnetic recording heads, machine tool positioning and other servo applications where overshoot is intolerable. It provides a means of driving mechanisms without costly conversion from digital to analog servo voltages. Called the Digitran, this new component is capable of bidirectional digital stepping rates up to 60 steps per second. The large step travel of 180 degrees permits designers to increase available torque in exchange for angular travel by the addition of standard servo gear heads. Typical motor with 180:1 gear head produces 80 inch-ounces of torque for a 1 degree step. The Digitran Company, Pasadena, California.



Circle No. 178 on Inquiry Card



Low Torque, High Speed Counter

Low torque (0.5 inch-ounce) and high operational speed (2,000 rmp) distinguish the new Model 7102 DIGICON, a mechanical counter with electrical readout. This unit will interest systems designers who want to read a number visually and also have contacts available for control or remote indication. It is applicable to the control and location of poison rods in nuclear reactors, and as an accessory to spectrophotometers to record data on automatic production recording equipment. DIGICON gives visual readout counts up to 9999.9. Number wheels, with high current carrying capacity, are lighted for visual and photographic clarity. DIGICON is 1.7 inches x 1.9 inches x 1.9 inches and is ruggedized for environmental extremes from minus 40 degrees C to plus 85 degrees C; it withstands acceleration up to 10 G's. The Digitran Company, Pasadena, Calif.

Circle No. 172 on Inquiry Card

Antennas and Microwave Components

Continuous open-leaf short-form catalog lists over 850 standard items in the antenna and microwave fields—by far one of the most complete and comprehensive groupings in this field. Most of the components can be purchased from stock, otherwise nominal deliveries can be met.

Source: Diamond Antenna & Microwave Corp. Wakefield, Massachusetts

For your copy: Circle No. 90 on Inquiry Card

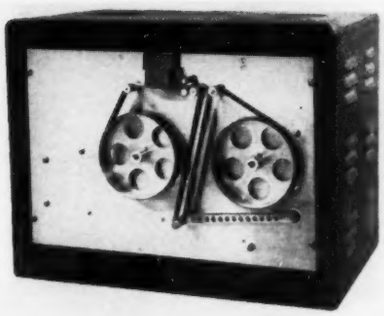
Plastics for Electronics

4-page short-form catalog gives brief descriptions of many plastic materials available for electronic applications: microwave absorbers, casting resins, plastic foams, plastic rods and sheets, reflectors and luneberg lenses, plastic surface coatings, adhesives, cements and sealants, impregnating resins, and laminating resins.

Source: Emerson & Cuming, Inc. Canton, Mass.

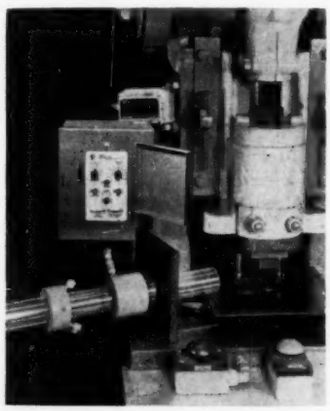
For your copy: Circle No. 209 on Inquiry Card

Miniature Random Access Memory



A new miniature memory unit, Miniran, stores up to 10 million bits with an average access time of less than ½ second. Unit consists of a tape transport mechanism with completely transistorized drive and programming circuitry. Each of the two reels on the transport contain approximately 35 feet of one-inch tape which, started from its center, can be swept past the head in either direction in less than ½ second. Direction of tape travel is determined by input programming. At end-of-tape a pre-programmed 50 millisecond stop is inserted, after which the tape travel is reversed. Miniram can be programmed to return to the center of the tape after each "look up" or can be stopped at end-of-tape or any point desired. For applications where storage of more than 10 million bits is required, Miniram transport units may be added to form a bank capable of storing virtually any amount of digital data. Since the transport unit is designed for standard rack mounting and is only 12 inches high, a number of units may be mounted in a single rack. Potter Instrument Co., Plainview, L. I., New York.

Circle No. 110 on Inquiry Card



Radio Coil Stops Punch Press "Double-Heading"

A radio frequency coil mounted on a cast acrylic tube comprises the detection unit of a new "die-saver" press control.

The electronic control is installed on punch presses to eliminate "double-heading"—the completion of a press stroke on top of an unejected part in the die. "Double-heading" is a principal cause of die breakage and press down time.

In operation the electronically transparent cast acrylic tube is attached at the die face, next to the ejection point. As each piece is ejected, a stream of compressed air blowing through the tube draws the part through the coil, breaking the radio frequency field and thereby closing a set of contacts in the control panel. When a piece fails to eject in the required time, the contacts open and the press stops.

By adding the acrylic tube mounting, the designers corrected a condition in which the press control was oversensitive. The radio frequency coil of the "die-saver" is spaced at least 12 inches to 24 inches from the die face, since otherwise its field might be broken by the mere up and down movement of the press. In earlier models, the coil was simply suspended the required distance away. But then the stamped pieces, scattering as they left the ejection point, would sometimes fall wide of the coil and the press would be stopped unnecessarily. In its present design, with plastic tube mounting and compressed air stream, the press control detection unit is unfailingly accurate with even the most miniature stampings.

"By relieving the operator of the tension of guarding against double-heading," the manufacturer reports, "the press control promotes safety and raises production.

The press control unit may also be used to automate the press and to count stamped parts. Robotron Corp., 21300 W. Eight Mile Road, Detroit 19, Michigan.

Circle No. 111 on Inquiry Card

WORTH FILING

Thermocouple Wires

Eight-page catalog illustrates, according to insulation and construction, Thermo Electric's thermocouple and extension wires; contains a number of uesful charts on calibration symbols and wire color codes, wire resistances, weights and electrical properties, and insulation characteristics.

Source: Thermo Electric Co., Inc.
Saddle Brook, N. J.

For your copy: Circle No. 220 on Inquiry Card

Liquid Heating Problems?

Your Chromalox Man has the ANSWERS

Backed by the industry's most complete line of electric heaters, he has heaters specifically designed for oils, water, asphalt, paraffin, salt baths, corrosive solutions and heat transfer media. Standard heaters are ready for immediate shipment from the world's largest stock.

Call your Chromalox Sales-Engineering Representative for clean, safe, economical *Electrical* answers to *all* your heating problems. Or, write to:

2607

Chromalox Electric Heat
Edwin L. Wiegand Company
7900 Thomas Blvd. · Pittsburgh 8, Pa.

CIRCLE NO. 12 ON INQUIRY CARD

EYETRON

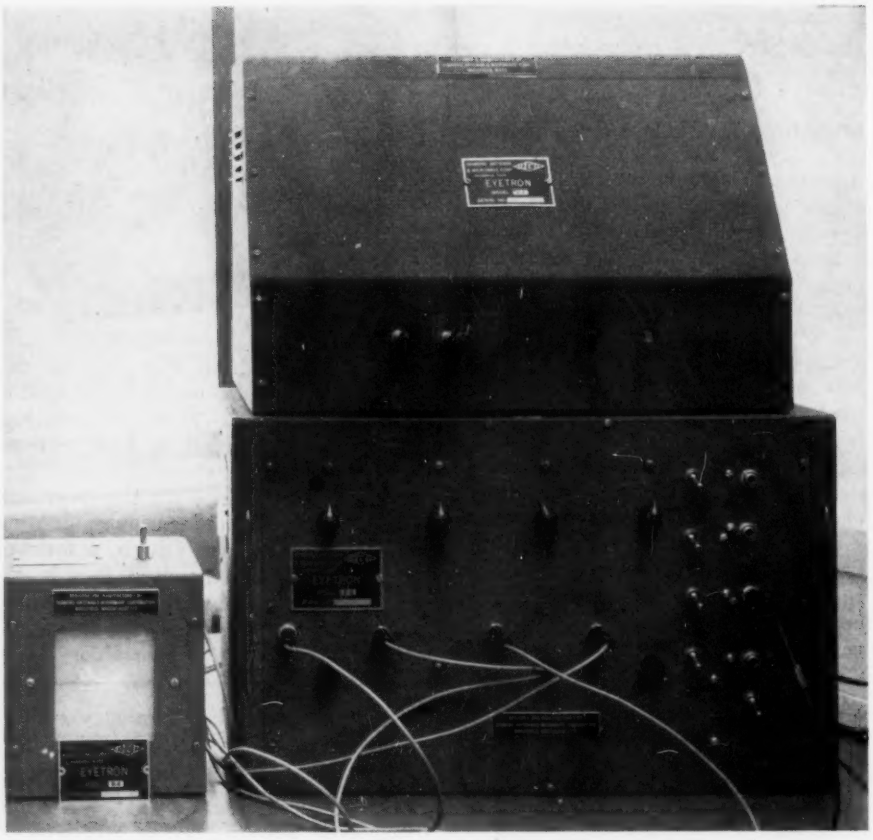
Converting Radio Energy Into Visible Light

The EYETRON, a device which converts microwave radio energy into visible light, functions as the human eye does. It is sensitive to microwave energy and produces on a screen a picture of scenes which are illuminated by microwaves or which contain sources of microwave radiation. The picture appears on the screen instantaneously and continuously so that it corresponds in all respects to the appearance of the scene to the human eye. Developed by Diamond Antenna & Microwave Corp., Wakefield, Mass., the EYETRON restores vision at times when normal vision is obscured by fog, smoke, haze, or other conditions opaque to visible light but transparent to microwave radio.

Albert S. Hovannesian, Diamond A & M's president, explained that EYETRON is not radar. In comparison, EYETRON is different in principle and application. A radar sends out a pulse of energy in a particular direction and waits for echoes to return from objects in this direction. It has a minimum range since the receiver cannot operate while the transmitter is on. If more than one direction is of interest, the radar must scan, examining directions in time sequence. Various displays are used to present the information which the radar obtains, but these are unnatural and require a certain amount of interpretation by skilled operators.

The EYETRON, explained Mr. Hovannesian, looks simultaneously at all directions in its field of view without scanning and displays images simultaneously of all objects in the field of view. It has no minimum range. The presentation of a true perspective of the scene requires no interpretation. The EYETRON is passive, the source of microwave radiation being one or more sets of auxiliary equipment. There can be no interference between several EYETRONS operating in the same area as there would be in congestion of radar sets.

The unit consists of a microwave collector which separates incoming waves according to their angle of arrival, channeling all waves from a given direction. A viewing screen displays a spot of light for each direction from which microwave energy is arriving.



Diamond Antenna and Microwave's EYETRON fills the gap where radar is useless at close proximities and where radar type presentation requires skilled operators. The system does not transmit and receive pulses to show only pips on a tube, and does not scan in range or azimuth as radar does; nor does it have a minimum range limitation. It operates at very low voltage without a cathode ray tube for viewing purposes. It produces a full picture of objects and scenes instantaneously and continuously, corresponding in every detail to that which would be seen by the human eye under ideal seeing conditions. Where several radar sets in one area would cause interference with one another, Diamond Antenna and Microwave states that these units in congestion enhance the total performance.

For airport applications, runway is outlined by a series of beacon transmitters in the same manner that runways are now outlined by marker lights. Obstructions, such as hangars, could be illuminated by a microwave antenna in the same manner that they are now illuminated by flood lights. EYETRON "sees" the beacon transmitters as well as the energy reflected from the obstruction and shows on the screen a true perspective picture of the scene.

The EYETRON is made practical by novel concepts in circuitry which are proprietary items of Diamond Antenna and Microwave Corporation, and for which applications have been filed with the U. S. Patent Office. The concept employed on the transmitted energy enables the use of extremely narrow band, high sensitivity circuitry. Mr. Hovannesian expects the unit to be constructed in extremely miniaturized versions using low power transistors so that the electronics necessary for a chosen number of picture elements will be packaged in a volume hitherto unthought of. Under these conditions, Mr. Hovannesian predicts that the unit will operate at a small fraction of the power required for radar. Even a small storage battery should be adequate for many hours of operation. The device is very economical in construction and simple in operation when compared to radar systems.

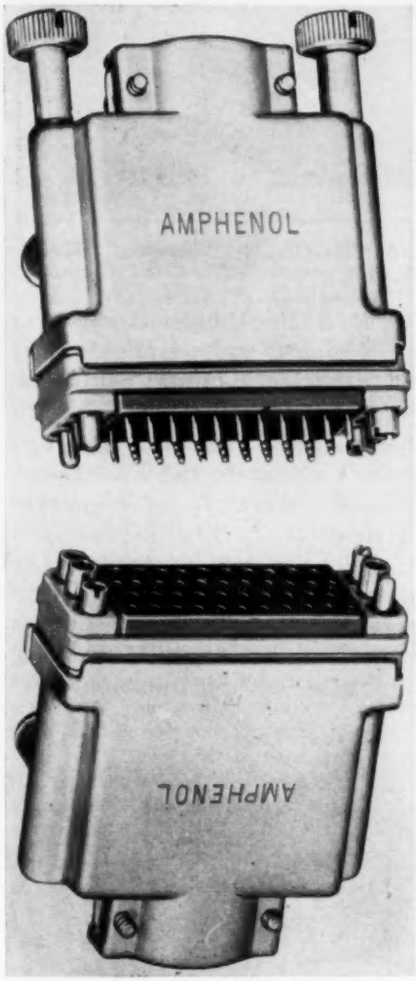
Furthermore, Mr. Hovannesian pointed out, the device may be so constructed as to be selectively sensitive at several frequencies in such a manner as to visually display different colors on the viewing screen. In addition, MTI or moving target indication can be incorporated in the device by simple circuitry changes.

Specific design details are still company classified. Current plans under investigation involve application to: airport landings, aircraft carrier landings, missile rocket tracking, ocean going ships, small harbor craft, battlefield surveillance, mobile battlefield use, coastal defense early warning systems, low flying aircraft detection, ocean lighthouse use, commercial vehicles.

Circle No. 101 on Inquiry Card

New Rack & Panel Connectors

Complete line of miniature rack and panel connectors with insert arrangements of 34, 42 and 50 removable "Poke Home" contacts are now available. Under the patented "Poke Home" design, contacts may be automatically crimped to wire outside the body of the connector and then inserted into the insert. In the event that a circuit must be relocated or is damaged and must be replaced, it is not necessary to remove and replace the whole connector but only the specific



contact; this is easily done by means of a simple removal tool. Connectors are available as inserts with or without jackscrews, or in straight or right angle housings with or without jackscrews. Dielectric material is diallyl phthalate; shells are cadmium-plated aluminum; contacts are gold-over-silver plated. Silicone rubber face gaskets are also provided. Connectors are rated at 7.5 amps at 500 volts d-c at sea level and 7.5 amps at 125 volts d-c at 70,000 feet. Temperature range is −65 degrees C to +200 degrees C. Amphenol Electronics Corporation, Chicago 50, Illinois.

Circle No. 167 on Inquiry Card

New... Valcor

ALL-WELDED V-28100 Series Features Reliability

...the only all-metal, in-line solenoid valve with an optically-flat seat!

The all-new Valcor V-28100 Solenoid Valve eliminates all internal or external non-metal seals. All-welded, all-metal, the V-28100 is designed to minimize temperature and media problems for the long life of the valve. The V-28100 features an optically-flat, hard-faced seating, one of the many unusual engineering designs responsible for Valcor's wide acceptance throughout industry. And because of its all-metal construction, the shelf life of the V-28100 is unlimited.

Featuring compact size and low weight, it is especially valuable in missile and aircraft design.

Write for complete technical data and literature today.

VALCOR SOLENOID VALVES

The new V-28100 series cover the following range—

MEDIA: Fuels, hydraulics, pneumatics, liquid gases
TEMPERATURE RANGE: -300°F to +600°F
DIMENSIONS: 1.25" x 2.60"
RESPONSE: 15 milliseconds
VOLTAGE: 18-30 volts DC
PRESSURE RANGE: 0 to 3,000 psi
FLOW EQUIVALENT: .020 to .125 sharp edge orifice

VALCOR ENGINEERING CORP.

5374 CARNEGIE AVENUE, KENILWORTH, NEW JERSEY
SEE YOU AT THE DESIGN SHOW . . . BOOTH 567
FOR MORE INFORMATION CIRCLE 13 ON INQUIRY CARD

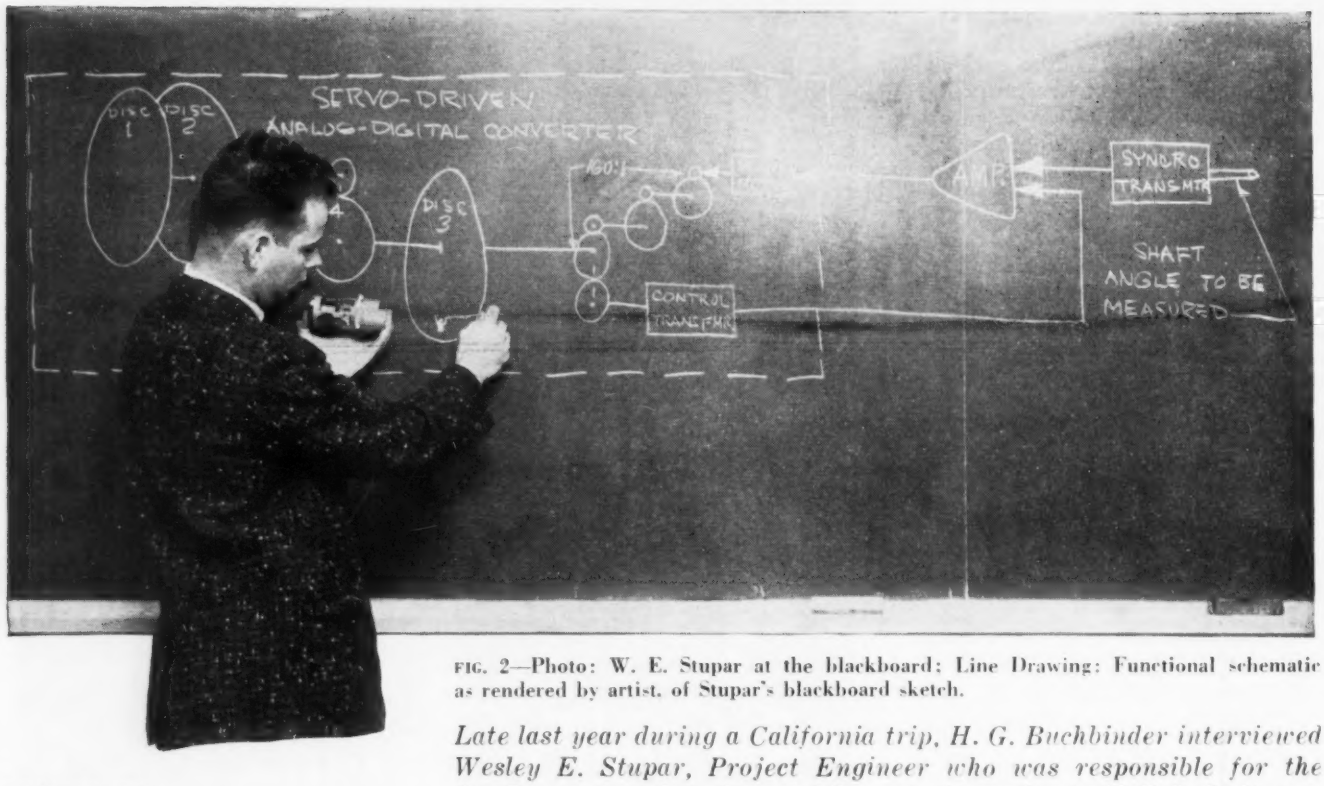


FIG. 2—Photo: W. E. Stupar at the blackboard; Line Drawing: Functional schematic as rendered by artist, of Stupar's blackboard sketch.

ANALOG TO DIGITAL CONVERTER

Double Brush Design Eliminates Ambiguity in Generating Sequential Binary Code

Late last year during a California trip, H. G. Buchbinder interviewed Wesley E. Stupar, Project Engineer who was responsible for the development and design of Librascope's analog-to-digital shaft converters. Their interview dealing with Librascope's new 7-bit digit sine-cosine, analog-digital converter was taped, pictures taken, and drawings selected, and upon Buchbinder's return to the East Coast, promptly lost. When a thorough two months' search failed to uncover the missing tape, Buchbinder called Kenneth J. Slee, Librascope's Public Relations Director, and prevailed upon him to re-interview Mr. Stupar. Because we believe in always giving credit where credit is due and because of the clarity of the questions and answers, we are presenting the interview as it came from the tape. Here, then, are the design details of Librascope's new 7-bit analog-digital converter.

K. J. SLEE: Wes, why don't you start out by describing your Fig. 1.

W. E. STUPAR: Figure 1 is an assembled view of the 7-bit digit sine-cosine analog-digital converter which has intrinsically incorporated a set of servo components to position the converter according to a signal received from a synchro transmitter.

K.J.S.: What are the unique features of this converter?

W.E.S.: Well, the unique features include its small size compared to the job that it does. It indicates simultaneously the sine and cosine of the angle of the synchro transmitter in binary digital form to approximately one part in 200 and it gives this indication for the complete 360 degree rotation of the transmitter shaft. In general, it is very compact and its construction is unique.

K.J.S.: What applications do you see for this product?

W.E.S.: I see applications principally in its use as the input to a computer where the computer is required to perform mathematical operations on the sine and cosine of the position of some shaft; for instance, this might be the sine and cosine of the angular position a radar antenna has assumed with respect to some reference line for the purpose of navigation or tracking or range finding; or it might be used in some machine tool control or processing problem where it is desired to perform digital computations on the basis of any shaft position that one might have.

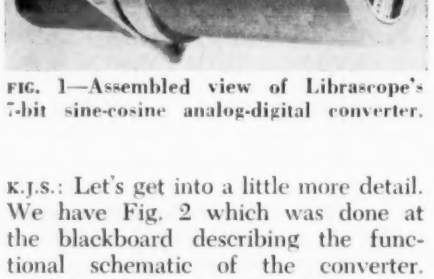


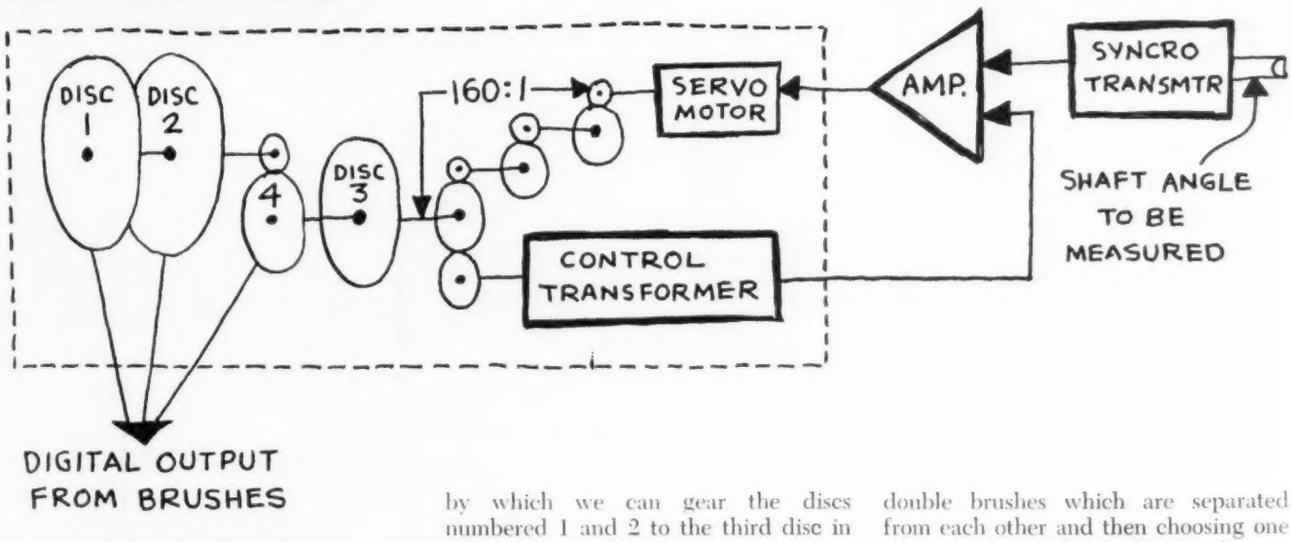
FIG. 1—Assembled view of Librascope's 7-bit sine-cosine analog-digital converter.

K.J.S.: Are all models made with a servo-driven head on them?

W.E.S.: No; this particular model is, but, in general, most of the converters that are made by Librascope are simply converters, *per se*, and have a shaft input. In other words, they give a digital representation of their input shaft. Rather than going through an electrical servo link, one would directly connect the shaft or gear the shaft to the shaft to be measured.

K.J.S.: Let's get into a little more detail. We have Fig. 2 which was done at the blackboard describing the functional schematic of the converter. Would you mind explaining what is going on inside the converter with respect to the package?

W.E.S.: Figure 2 shows the converter as it would be used in a system that communicates the sine and cosine of some shaft position to a computer. The right-hand side of the picture shows a



synchro transmitter which would be connected to the shaft, the angle of which is to be measured. The output of the converter is not shown on the picture; however, the output would be electrical connections to the brushes on the code disc shown in the picture and the brushes would be connected to the computer to give the desired digital signals. Let us asume that in operation it is desired to servo the position of disc No. 3 in the picture to follow the position of the synchro transmitter shaft. This is accomplished through the use of the servo motor and the control transformer within the converter. The control transformer serves as a synchro reference indicating at all times the position of disc No. 3. The position indicated by the control transformer is then compared to the output of the synchro transmitter which is, in essence, the desired position. Any difference between the two signals, the one from the control transformer and the other from the synchro transmitter, is used to drive an amplifier which, in turn, drives a motor and causes, through gearing, disc No. 3 to move in such a direction that it will drive the error to zero and cause disc No. 3 to be positioned identical to the position of the synchro transmitter shaft.

K.J.S.: How many discs does this converter have in it to get the desired digital output?

W.E.S.: The converter has three discs altogether and this is a unique feature in itself in that not too long ago it was believed that one couldn't make a sine-cosine converter with more than one disc because of the problems in laying out the digital patterns on the disc. But we have devised a method by which we can gear the discs numbered 1 and 2 to the third disc in such a manner that discs 1 and 2 turn at four times the speed of disc 3. This method permits easier manufacture of the disc pattern. Because they rotate at a higher speed, the resolution is not required to be so high. The main feature that allows us to use this multiple disc construction is the double brush system in the converter that eliminates ambiguity.

K.J.S.: Is this double brush system unique to Librascope?

W.E.S.: There are some systems very similar to the double brush system we have, but what we call the double brush system is unique to Librascope.

K.J.S.: Would you mind explaining a little bit about the double brush system and then we'll get into the working print on the sine-cosine converter?

W.E.S.: To explain the double brush system you have to first be familiar with the problem of ambiguity. The problem of ambiguity is that in generating a sequential binary code, that is, a code that counts in mathematical binary significance serially, the bits of the number are sometimes required to change at the same time; for example, the least significant bit might be required to change from a 1 to a 0 at exactly the same time as the second least significant bit changes from a 0 to a 1. If these transitions do not occur exactly simultaneously, an erroneous number is generated; these erroneous numbers are referred to as ambiguity. To eliminate the occurrence of these ambiguities, our system allows all the more significant bits to change only at the time that the least significant bit changes. This design is accomplished by replacing single brushes on the bits of more significance with double brushes which are separated from each other and then choosing one or the other of the double brushes on the basis of the least significant bit; that is, whether it is high or low. In this manner the transitions are skipped over for one particular brush and the bits of more significance are controlled by the least significant bit.

K.J.S.: It is my understanding that these brushes are staggered?

W.E.S.: Yes, the brushes are staggered because, rather than controlling all the discs by the least significant bit, we can control the second bit only by the least significant bit and then control the third least significant bit by the second least significant bit. This turns out to be unambiguous and it further allows wider tolerance on the location of the brushes. In fact, we always control a particular bit by a preceding bit so that maximum tolerance is realized.

K.J.S.: Well, Wes, let's take a look at what is actually going on inside the converter.

W.E.S.: In looking at the two photos of Fig. 3, we see the inside of the converter with a number of gears in the two gear trains, the rear gear train and the forward gear train.

K.J.S.: Are these gears spring loaded?

W.E.S.: Yes, the gear train nearest the electrical connectors are spring loaded.

K.J.S.: Which gear train is the servo gear train, that is, the motor interconnecting disc No. 3, the drive motor and the control transformer?

W.E.S.: There is one spring loaded mesh in there, the gear connected to disc No. 3. That gear is spring loaded, not

MORE PERFORMANCE PER DOLLAR
than any other amplifier

MODEL USA-3

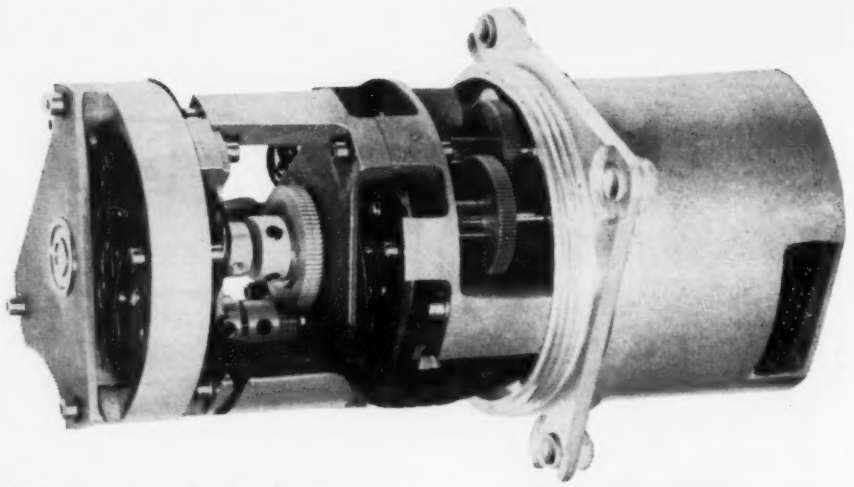
- RELIABILITY: No electrolytic capacitors or glow tubes. Designed to prevent self-destruction even when the output is short circuited.
- DRIFT, NOISE, OFFSET: Under 100 microvolts
- LARGE OUTPUT VOLTAGE: 230 volts peak-to-peak
- WIDE FREQUENCY RANGE: DC to 100kc (attenuation less than 3db) when connected as a gain-of-ten amplifier.
- COMPACT SIZE: 7" x 2½" printed circuit board, mounts by any convenient method.

One of several types of modular packaging available at slight extra cost.

For full information, write George A. Philbrick Researches, Inc., Dept. EM 1. Ask for Bulletin USA-3.

GEORGE A.
PHILBRICK
RESEARCHES, INC. *HUbbard 2-3225*
230 Congress Street, Boston 10, Mass.

CIRCLE 14 ON INQUIRY CARD



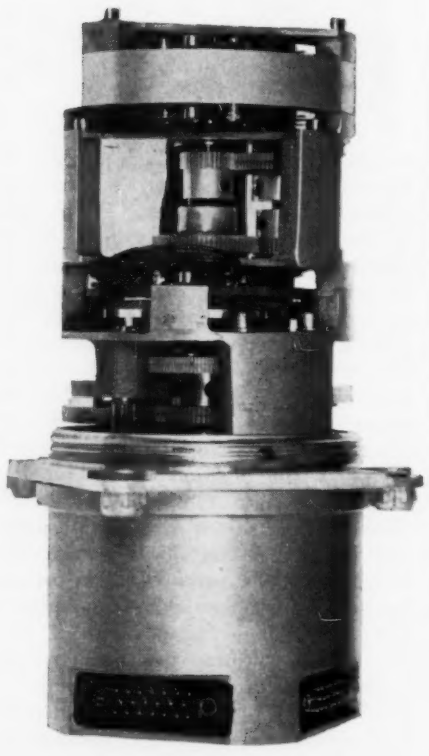


FIG 3—Two views showing the gear trains of the converter.

so much for accuracy reasons but that backlash in general is undesirable from a stability standpoint in the servo system. We spring load the gear so that the servo motor won't oscillate across the backlash. In the gear train farthest from the electrical connectors, we spring load both meshes in the interest of obtaining the highest accuracy because discs 1 and 2 are the discs of highest resolution in generating the functions and it is necessary to propagate the accuracy in positioning disc 3 according to the transmitter shaft through the discs 1 and 2 to maintain the accuracy of the digital conversion.

K.J.S.: Is there any particular design feature with regard to either the gear trains or the disc assembly on these pictures?

W.E.S.: The processes that are used aren't novel; they're more or less standard practices. The care and skill that goes into executing the processes are responsible for the quality of the disc. The photo etching is very carefully controlled. First of all, the material is carefully prepared. It is polished to a high finish and the photo etching is controlled to give uniform contact. Electroplating gives a high quality of deposit on the surface and then the discs are flushed by pressing them in a dust-free die. All these steps go into making a smooth contact surface.

K.J.S.: How about the environmental considerations; for example, is there any unique design problem handled here with respect to environment?

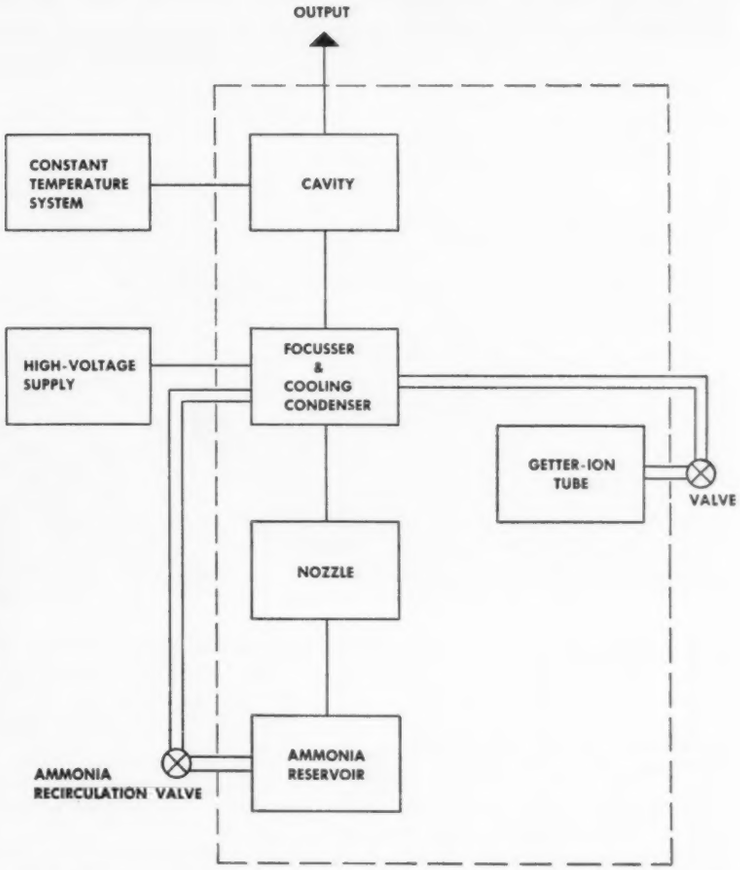
W.E.S.: There is nothing really unique in this respect. Of course, it was designed to pass very stringent environmental requirements and it is hermetically sealed and very rigidly constructed with materials that will not corrode and, in general, designed to military specifications.

K.J.S.: Do we make the sine-cosine converter in other configurations and also other bit ranges?

W.E.S.: Yes, we make an 8-bit unit (this is a 7-bit unit) which is about twice the size. We make it in a servo-driven form and also just with shaft input. We have some ideas for making units with approximately 10 bits of resolution and more but these are just ideas and we haven't had sufficient reason to go any further than that.

K.J.S.: Well, I think we did very well and if Harold doesn't lose this tape we'll be in good shape.

Circle No. 156 on Inquiry Card



Block Diagram—PRD Ammonia Maser Oscillator Tube. Ammonia-type maser operation is based on the controlled flow of molecules within a low pressure system into a region of an electrostatic field. A condensation chamber, cooled by liquid nitrogen, surrounds the electrostatic field. The electrostatic field focuses the molecules in the upper energy states into a narrow beam for passage into a high-Q resonant cavity operating in the TM_{010} mode. Molecules in the lower energy states are deflected away from the cavity and condense on the cooling chamber walls. When ammonia molecules entering the cavity regress to their lower energy states, a stimulated emission at a stable frequency results. Electromagnetic oscillation is sustained as long as there are a sufficient number of molecules in the beam.

AMMONIA-TYPE MASER OSCILLATOR

Better Than One Part in One Billion Stability

The first portable, sealed ammonia-type maser oscillator which generates a 23.8701294 KMC/sec signal at ±0.0000005 KMC has been developed by Polytechnic Research & Development Co., Inc., Brooklyn, N. Y.

The company says that results obtained from their first two operational models indicate that the PRD Ammonia Maser Oscillator, which generates a highly stable frequency in the K-Band, will possibly have important applications in space guidance and navigation, coded communications and Doppler navigation. This portable unit weighs only 20 pounds and occupies a volume of 1/4 cubic foot with a stability of better than one part in 10^9 (1,000,000,000). These masers have excellent potential as basic research tools for establishing new theories and re-evaluating existing theories in physics, chemistry and all branches of science.

Present models are experimental units available to science and industry at a cost of about $7000.

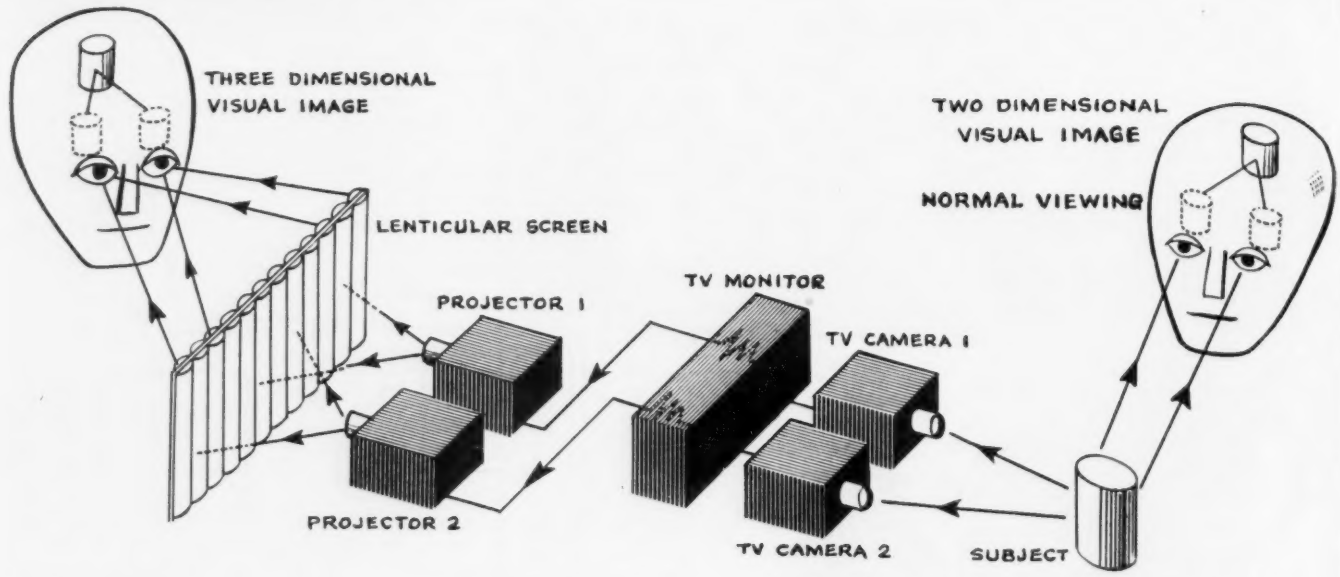
Mr. Herbert A. Finke, general manager of the company disclosed the following design and performance details. The unit is a molecular beam oscillator which can operate more than 500 hours without breaking the vacuum seal. By the addition of inexpensive replacement parts, an additional 500 operating hours can be obtained. Its shelf life is a minimum of one year.

The frequency of oscillation of the PRD Maser will not vary by more than one part in a billion. Its operation is indicated by the accompanying block diagram.

PRD engineers, Mr. Finke said, have devised a unique way of recirculating the ammonia to the reservoir after 50 hours of operation, thereby eliminating the need for auxiliary pumping equipment. Recirculation takes only one hour and can be performed by unskilled personnel.

The high vacuum so essential to the system, Mr. Finke pointed out, is maintained by incorporating a getter-ion tube, which flashes periodically to remove the residual gases and continuously removes the rare gases. Stability of the resonant cavity is assured by a temperature control system which regulates to within ±0.02 degrees C.

Circle No. 158 on Inquiry Card



Simulation system uses a two-channel electronic camera and transmission set-up for the pickup, electrical translation and eventual reproduction on the directional screen of the two images corresponding to the images and binocular vision. The directional characteristics of the screen are such that light emanating from two point sources separated by a proper angle from the screen are channeled into two well-defined areas. The viewer, seated at the proper location, receives two images bearing the correct relationship to the subject viewed to reproduce the full three dimensional effect.

3-D VIEWING

Lenticular Screen Simulates Tri-Dimensional Images

The physical and psychological aspects of binocular vision and the basic optical principles involved are fairly well understood. Briefly, any total visual impression is a synthesis of two pictures perceived by the individual eyes. Pictures are different because the distances between the points on the surface of the subject and the respective eyes are different, except for the central points; perception of depth is a result of the interpretation of these differences.

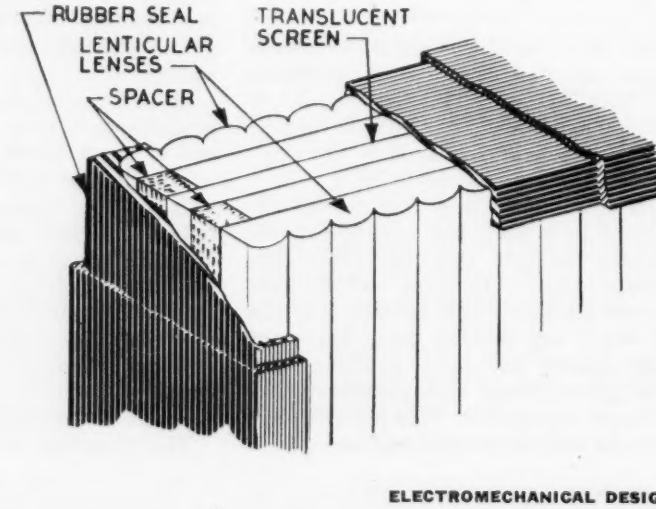
The degree to which depth is perceived depends on how discernible these differences are. If the subject distance is considerable, the perception of depth is lost. On the other hand, at close range, depth is an important part of visual information and is essential for accurate interpretation of spatial relationships.

Reproduction of a three dimensional picture on a flat surface calls for the projection of two images bearing the proper relationship corresponding to binocular vision. However, mere projection of two pictures does not, in itself, produce a three dimensional picture since each projection is viewed by both eyes.

Thus, it becomes necessary to employ a selective means for the proper channeling for the two pictures. A very simple method relies on assigning two colors to the individual pictures and the use of appropriate filters in the viewing spectacles. Also, polarized light in conjunction with appropriate filters can be used to advantage and is free from any color limitations. Another possible method relies on successive projections and a synchronized viewing shutter. These systems suffer from a common disadvantage: the necessity of viewing accessories that destroy normal vision when the viewer looks away from the screen.

To eliminate the need for such accessories, designers at Dusal Instrument of Long Island City, New York, have developed a lenticular (directional) screen that columnates and channels the light originating at a projection source. The screen illustrated in Fig. 1 consists of a translucent plate covered on both sides by a series of lenticular lenses of methyl methacrylate cast rod, polished and ground to optical quality for the proper focal length. These lenses are assembled with relation to each other so that each picture, from either one of two projectors, when viewed at the proper distance with one eye, gives only a flat picture. Looking at the screen with both eyes shows two slightly different images, thereby giving a three dimensional effect.

According to William Lewi, Dusal's Chief Engineer, size and spacing of the lenticular lenses are of the greatest importance since these factors determine the depth and clarity of the picture. Any side motion or twisting of the viewing axis does not affect the three dimensional effect created by the screen. The screen also accepts color pictures as well as black and white. The main function of the unit



Design details of lenticular screen.

is to screen out one picture for each eye, thus permitting each eye to see one picture only.

VISUAL SIMULATION SYSTEM

When applied to a synthetic training device, the Dusal system utilizes a closed loop television set-up at the model array of the visual environment to be simulated, and at the end of the presentation it uses a lenticular screen which converts the simulator environment into the realistic tri-dimensional image. If differential motion is required, the model array is actuated through a servo drive system.

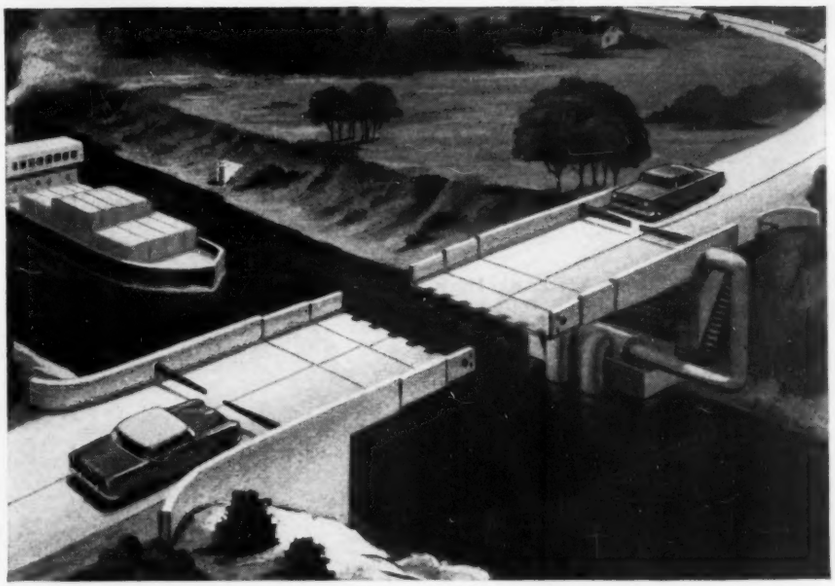
Two TV cameras controlled by computing and amplifying equipment pick up the image of the model array and transmit it to projectors focused on one or more lenticular screens visible to the trainee. Varying the distance between the two TV cameras changes the depth of field and varies the degree of depth perception to the viewer. The control position and monitor screen are at the instructor's console. A repeater screen and a set of duplicate instruments and controls can also be set at the instructor's station, slaved to the comparable master units available to the trainee.

To eliminate human error and elements of instructor judgment in the evaluation of trainee performance, a system of automatic scoring with or without automatic recording has been tied into the system. Dusal claims that virtually any desired parameters can be automatically recorded or proficiency of a specific trainee function can be automatically scored against a base of time or predetermined tolerance. Final presentation of the three dimensional picture to the trainee appears on the screen which becomes an integral part of the training device; it is the only external visual environment available to the trainee. No extraneous and undesirable visual references are visible.

Mr. Lewi states that the unique feature of the system is the application and combination of relatively conventional closed circuit television techniques with the specially designed lenticular screen. Other component equipment of extended systems employ electromechanical and electronic closed loop servo techniques and high precision analog computing devices. According to Mr. Lewi the system is applicable to synthetic training devices for flight training, naval craft tactical training, gunnery training, in-flight refueling training, tank operation training, amphibious landing tactical training, as well as non-military training projects such as driver training and remote control radiation work.

Circle No. 104 on Inquiry Card

MARS outstanding design SERIES



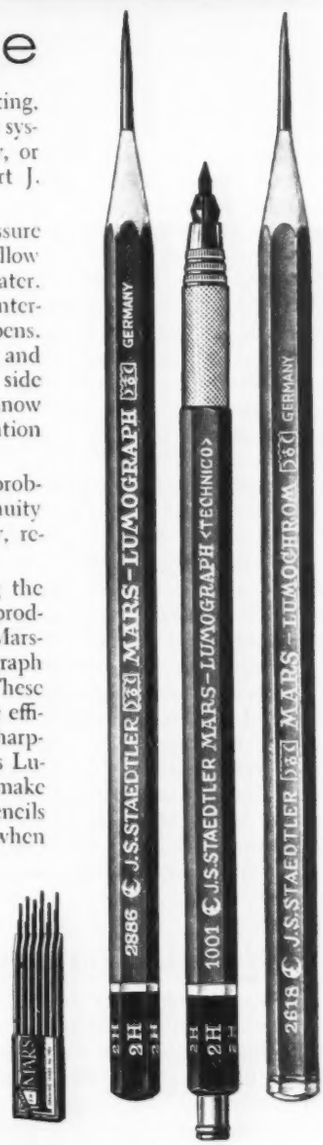
automated bridge

The bridge of tomorrow will be self-activating, equipped with electric-eye controls and an anti-freeze system. No overhead structures will obstruct the view, or interfere with radio reception, according to Robert J. Companik of Chicago.

In his design, the bridge is operated by pressure pumps that draw water from the canal into the hollow structure and hold it shut by the weight of the water. To allow boats to pass, pressure is released, counterweights pull the sections together, and the bridge opens. An electric eye down the canal activates the opening and the bridge does not close until an eye on the other side is passed. Heating units keep both eyes free from snow and ice, and a brine system keeps the bridge in operation in freezing weather.

Many ingenious solutions to traffic and other problems are on the boards today. To make their ingenuity clear, and to translate them from idea into reality, requires the best of drafting tools.

In pencils, of course, that means Mars, long the standard of professionals. Some outstanding new products have recently been added to the famous line of Mars-Technico push-button holders and leads, Lumograph pencils, and Tradition-Aquarell painting pencils. These include the Mars Pocket-Technico for field use; the efficient Mars lead sharpener and "Draftsman" pencil sharpener with the adjustable point-length feature; Mars Lumochrom, the color-drafting pencils and leads that make color-coding possible; the new Mars Non-Print pencils and leads that "drop out" your notes and sketches when drawings are reproduced.



The 2886 Mars-Lumograph drawing pencil, 19 degrees, EXEXB to 9H. The 1001 Mars-Technico push-button lead holder. 1904 Mars-Lumograph imported leads, 18 degrees, EXB to 9H. Mars-Lumochrom color-drafting pencil, 24 colors.

J.S. STAEDTLER, INC.
HACKENSACK, NEW JERSEY

at all good engineering and drawing material suppliers

FOR MORE INFORMATION CIRCLE 14 ON INQUIRY CARD

"MITE" TELEPRINTER

High Speed Printing Without High Speed Mechanical Motion

A number of new "data read-out" devices have been developed in recent years to keep pace with requirements of automatic digital computers. Outputs have taken the forms of cathode ray indicators, magnetic tape, punched cards and tape, smoke printing, magnetic printing, electrostatic printing as well as alpha-numeric page printers. Page and tape printers have been used for many years in communication circuits and have been made to operate in response to as many as eleven types of Morse, synchronous printer and start-stop printer codes. Many new types of equipment, however, have required special input signals or operate at high rates of speed and are otherwise not compatible with existing communication equipment.

Bernard Howard, Vice President of Teleprinter Corporation, Paramus, New Jersey, stated at a recent meeting of the AIEE last February that civilian and military users have indicated that, although they anticipate a need for higher speeds in their communication circuits, they will probably use printers operating from the telegraph start-stop code for some time to come. The Armed Forces find it increasingly desirable to add electronic aids to their mobile and airborne units but are naturally reluctant to increase the size of vehicles and aircraft. Civilian users are increasingly aware of the desirability of printed communications and of a print-out device compatible with those systems most generally in use. In both these connections Mr. Howard said that the characteristics of reduced weight and cube, lower power consumption, and lower initial costs and maintenance become increasingly important.

NEW APPROACH TO CHARACTER POSITIONING

One of Teleprinter Corporation's design objectives in the development of "Miniaturized Integrated Telegraph Equipment" (M I T E) was to produce a machine capable of high-speed operation with a minimum of high-speed mechanical motions. This demanded a radically new approach to the method of deriving 64 mechanical positions from the five intelligence pulses in the start-stop code.

Figure 2 illustrates a basic principle applied to the M I T E. If a strip of type were substituted for the weight, then an elementary character positioning device will have been provided. The 32 character length of the strip would, however, require a rapid motion of the type strip if the first and last letters on the strip were called for sequentially.

The space and motion requirement could be reduced by arranging the letters in the form of a rectangle 8 characters long and 4 characters high and employing 2 coordinate motions. The space and motion requirement could be still further reduced by folding the rectangle into a half cylinder 8 characters long and with 4 faces and converting the linear coordinate motion used to choose one of the four up and down positions of the rectangle to rotary motions up to 180 degrees. This has been done in the M I T E, said Mr. Howard, with an 8-sided type cylinder which is 8 characters long. (See Fig. 3).

SYNCHRONIZATION

Synchronization of the M I T E printer with the transmitted signal, as with other 7.42 unit code printers, makes use of two pulses in addition to the 5 intelligence signal pulses. These are referred to as the "start" and "rest" or "stop" pulses. The "start" pulse effectively starts the rotation of the timing camshaft by releasing the start clutch. The "rest" pulse which is 1.42 units long occurs between the fifth signal pulse and that start of the next "start" pulse and allows a margin of error to exist between the motor speeds in the sending and receiving machines. The receiving camshaft rotates faster than the corresponding transmitting camshaft and comes to a stop during the stop pulse while the transmitting camshaft will rotate continuously during a continuous automatic transmission such as from a tape transmitter.

REDUCTION OF MECHANICAL SPEEDS AND LOAD

In the M I T E, the mechanism which controls the pulleys, and consequently the type cylinder, is arranged to reduce the speed of operation and mechanical load on the machine by gradually positioning the type cylinder while the signal pulses are being received rather than by storing the pulses mechanically as they are received and beginning the positioning of the type after the receipt of the last intelligence pulse. For this reason, and because the type cylinder is located behind the printing medium, there is no need for a neutral position of the type cylinder; and consequently, in the case of a repeated character, the pulleys and cylinder do not move.

SELECTION

Each of the five type positioning pulleys illustrated is positioned by a cam follower passing through the pulley housing. The cams which move these followers are each coupled to a clutch. The five clutches and their cams are mounted on a continuously driving shaft on which the clutches free-wheel when not engaged and to which they are capable of being sequentially coupled.

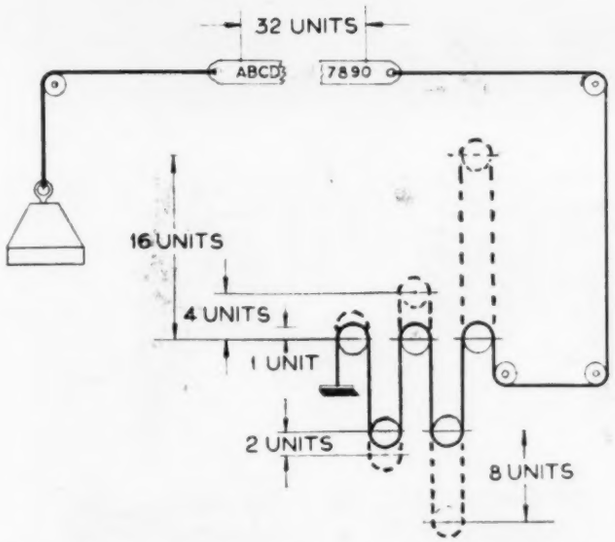


FIG 2—Schematic of a simplified print positioning device. One of the basic principles used in the M I T E is a unique application of one of the six "simple machines"—the pulley. If one end of the string is fixed and the other end is attached to a weight, a ½ inch movement of any pulley in a vertical direction will move the weight one inch. Next, suppose that each pulley is moved a different distance. Then the weight can be moved to any one of five different positions, depending on which pulley is moved. Finally, consider the possibility that each pulley is moved from its resting position twice the distance that the previous pulley travels and consider, also, that from one to five pulleys are moved at the same time. It can now be seen that there are 32 evenly spaced positions of the weight for all of the possible combinations of pulleys moved or not moved.

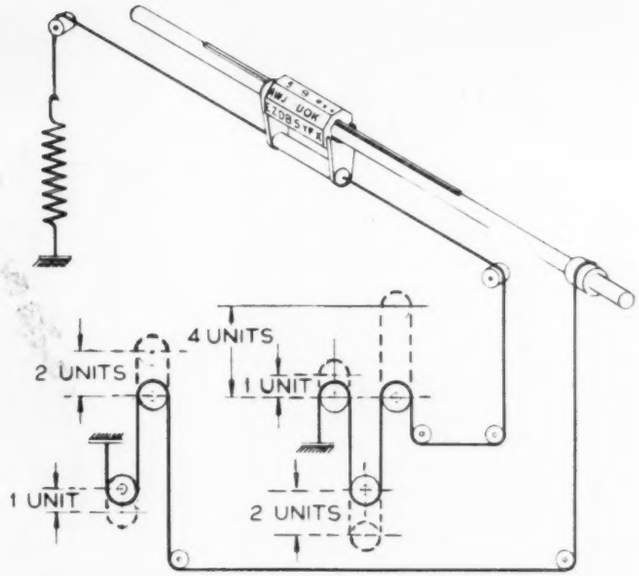


FIG 3—Schematic of print cylinder positioning method used in the "MITE." The 32 position half cylinder derived from the 5 pulley system is represented by 4 faces of the 8 sided cylinder and 8 lateral positions along those faces. The opposite four faces of the cylinder and the 8 lateral positions along those faces represent the "upper case" of the 32 basic positions so that the cylinder is rotated 180 degrees by the selection of "letters" or "figures" (lower or upper case) and the selection within that 180 degree segment is achieved by the basic 5 pulley system. Since a space is designated on the cylinder for every character or function that can be selected, the cylinder provides for 64 possible characters and functions, 2 of which are "letters" and "figures." In this way a small cylinder can accommodate 64 characters of standard teleprinted type. In operation the first two of the five intelligence code pulses control the rotary selection motions of the type cylinder while the last three pulses control the lateral motions.

In response to its signal as received by the Magnetic selector, each clutch will either engage the driving shaft for a 180 degree rotation or hold its position. The action of the clutch in each case depends on whether a mark or space signal is received and whether the clutch was left in mark or space position by the previous selection. If, for example, the No. 1 pulse for a given selection is a mark pulse, and if the No. 1 pulse of the preceding selection were a mark pulse, the No. 1 clutch will remain stationary. If a spacing pulse is received for No. 1 and the preceding No. 1 was a mark, the clutch will engage for a 180 degree rotation turning the cam affixed to the clutch correspondingly. The cam follower and the pulley controlled by it will go to the second of their two possible positions.

The actual release of each clutch is controlled by a pair of levers, one of which will engage the clutch and the other of which will stop it after 180 degrees. Each pair of levers is controlled by the selector and the instant of their release is determined by a sequence shaft which starts rotating upon receipt of the "start" pulse. The control of the clutch releases by the sharp drops in the sequence shaft cams is a feature which contributes markedly to accurate response and good range in the receiver. At the end of the receiving cycle, Mr. Howard explained, the sequence cam shaft rests while the main driving shaft on which the five pulley clutches now free-wheel continues to turn. The rotation of the main shaft after the receipt of the fifth intelligence pulse releases the special function-causing mechanism and either performs a mechanical function when one is selected or releases the print hammer to complete the character cycle.

RANGE ADJUSTMENT

The relative time at which the magnet armature position is sensed can be adjusted by moving the angular position of the timing camshaft with respect to the point at which the camshaft is released by the start clutch. This angular position of the start clutch release mechanism is connected to a calibrated dial which is marked in terms of percentage of one signal pulse. The variation in angular position which is possible without mutilation of a message is known as the "range" of a teleprinter. The M I T E has regularly been observed operating with ranges in excess of 75 points at 60 WPM in the laboratory, and has tolerated signal distortions in excess of 35 points under the same conditions. This range adjustment permits the printer to operate correctly from distorted signals such as may be received over long telegraph lines.

KEYBOARD

The mechanical and electrical connections between the keyboard and the printer are very simple. The keyboard circuit is in series with the printer signal circuit and when the keyboard is removed from the printer or put in storage position, the contacts on the printer are automatically shorted. A spur gear couples the printer motor to the keyboard operating shaft. The keyboard can be operated separately as a unit remote from the printer by using a separate motor. The keyboard operates as follows: The striking of any key, or the space bar, releases a clutch which permits the motor driven keyboard cam shaft to make half a revolution. At the same time five "code bars" are set up in a particular sequence according to which key is struck. These code bars will permit or block the motion of a series of cam follower

levers, which in turn will permit a series of five contacts to make contact or stay open and thus transmit the proper signal. The contacts are in series with the signal line and when no keyboard key is pressed, the contacts are closed.

REGULATION OF TRANSMISSION

To transmit the correct signal, these contacts must make and break at particular times, which would normally require a very accurate adjustment of each contact. This is avoided by providing a "master pulsing cam" on the keyboard camshaft. This operates a pair of contacts which accurately determine the timing of transmission while the five contacts affected by the code bars only determine whether or not each of the pulses is transmitted. The stop, 2 and 4 contacts are connected to one of the pulsing contacts and the number one, three and five contacts are connected to the other pulsing contact. In this way the adjustment of the five contacts is made non-critical and only the single pair of master pulsing contacts require adjustment.

MOTORS

The rotational inertia of the motor serves to integrate the pulses of mechanical power required for the printing cylinder positioning operations over the full character cycle. The total power required by the machine is 25 watts including the power for operation of the magnets so it can be seen that quite a small motor is used. When the power source is a-c, the motor operates at 3600 rpm for 60 cps and 12,000 rpm for 400 cps. These motors are synchronous with the line frequency and no speed adjustment is possible. When the power source is d-c, a 10,000 rpm motor is used and an adjustment governor is used for speed adjustment purposes. The motor speed is the same for all operational speeds, a single gear being changed for the various sending and receiving speeds.

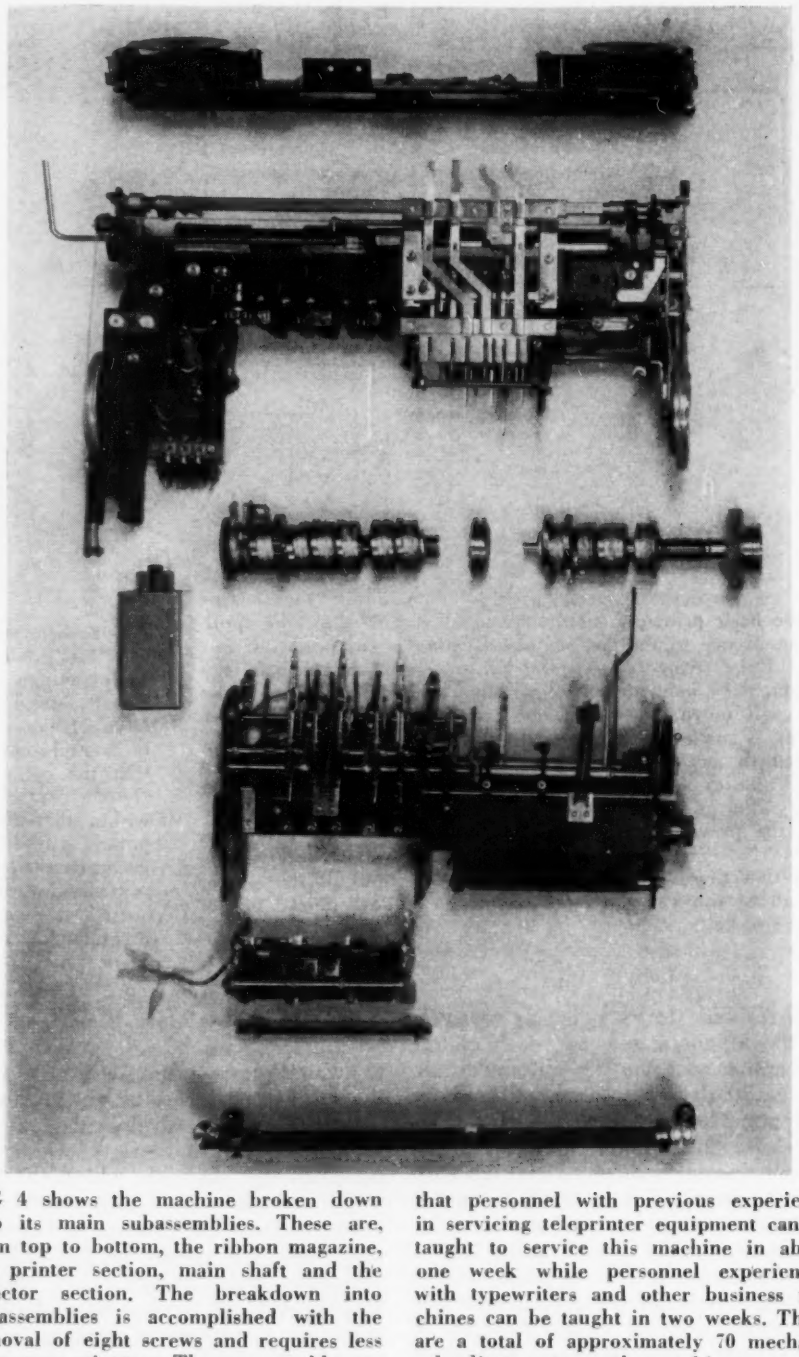


FIG 4 shows the machine broken down into its main subassemblies. These are, from top to bottom, the ribbon magazine, the printer section, main shaft and the selector section. The breakdown into subassemblies is accomplished with the removal of eight screws and requires less than ten minutes. The re-assembly requires less than ten minutes. All parts are readily accessible for inspection, lubrication and servicing. It is estimated that personnel with previous experience in servicing teleprinter equipment can be taught to service this machine in about one week while personnel experienced with typewriters and other business machines can be taught in two weeks. There are a total of approximately 70 mechanical adjustments on the machine, many of which are one-time factory adjustments to take up tolerances and which do not require readjustment in the field.

PAPER-TYPE RELATION

The type cylinder prints from behind the paper and the print hammer presses the inking ribbon against the front of the paper. This unusual arrangement maintains the type face clean at all times and also has the advantage of reducing mechanical wear on the inking ribbon which is struck by the smooth, regular hammer face rather than a sharp, irregular type face. The main advantage is that the operator has greater visibility of the printing as it is being received. A standard typewriter inking ribbon is used. The ribbon tilts back and downwards after each operation of the print hammer so that the last letter printed can be read. The placement of the type does not affect the ability of the printer to make carbon copies.

CARRIAGE RETURN

Unlike an ordinary typewriter, the paper does not move laterally but only the type cylinder moves. However, the term "carriage return" is still used. Since the type cylinder is quite light (about ½ ounce), fast return action is possible. This is important to ensure that the first character at the beginning of the new line is to be clear when only one character space is allowed for the carriage return operation. The M I T E is fitted with automatic carriage return and line feed which are triggered when the end of a line is reached without receipt of carriage return and line feed signals. The M I T E prints 72 characters per line on standard 8½ inch rolls.

Circle No. 154 on Inquiry Card

New Missile Gyro

A new subminiature rate integrating gyro for missile guidance and airborne armament control systems is said to incorporate manufacturing techniques that make possible a cost reduction of as much as 50 percent over comparable gyros. Techniques claimed to effect economy are:

- Simplified construction of both the moving coil and the magnet stator of the torque assembly
- Ease of initial alignment and simplicity in fabrication of the signal generator
- Use of solid stator for the spin motor, eliminating manufacturing operations necessary with conventional laminated assemblies.

Performance characteristics are said to be:

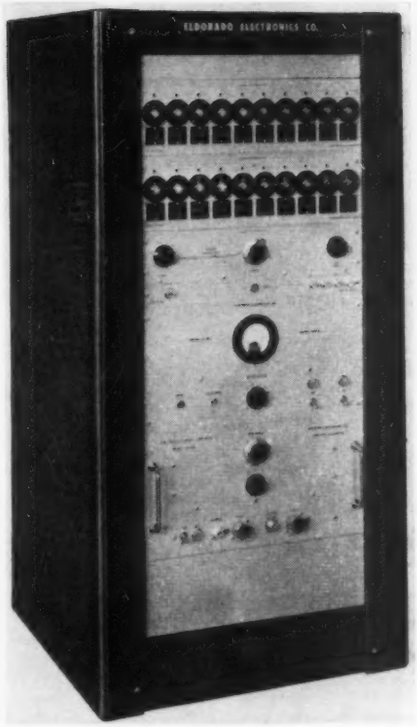
Range—plus or minus 120 degrees/second
Resolution—0.002 degree/second (earth's rate is 0.0042 degree/second)
Linearity—within 0.1 percent of maximum value
Mass Unbalance of Gimbal—0.3 dyne-centimeter
Dimensions—length, 3 inches; maximum diameter, 1-½ inches at mounting ring
Weight—7 ounces
Angular Momentum—3,000 dyne-centimeter seconds
Viscous Damping—3,000 dyne-centimeter/radian/second

Other characteristics of this development include: (1) a d'Arsonval torque generator for linearity of command and absence of residual torques; (2) a new signal generator for linear measurement of gimbal angle and the absence of residual torques; (3) jewel gimbal bearings for minimum friction; (4) a continuous temperature-controlled fluid damper for a constant damping factor; (5) a full-floated gimbal assembly to insure resistance to the effects of shock and vibration, and to insure low friction at the gimbal bearings; and (6) a high-torque spin motor capable of reaching synchronous speed of 12,000 rpm in four seconds. Westinghouse Electric Corporation, Baltimore, Md.

Circle No. 159 on Inquiry Card

Timer Measures Billionth of a Second

A new instrument known as "Nanosec" extends the art of time measurement three orders of magnitude from the millionth of a second range possible with present equipment. A billionth of a second (or nanosecond in the metric system of measurement) is the time it takes light to travel approximately three feet. Intended originally as a nuclear research tool, Nanosec can be used in the fields of radar, computer and solid state physics where requirements have outstripped the ability of conventional instruments. Nanosec applications include neutron time-of-flight measurement, determining the half-life of short-lived radioisotopes, fast coincidence circuit studies, delay line calibration in radar circuits, and transient time studies. The new timer consists of two basic elements, a time-to-amplitude converter and a 20 channel amplitude analyzer. In use, a time interval under measure is converted to a pulse of proportional height. The pulse height is measured by the amplitude analyzer and registered in one of the analyzer channels. Each channel corresponds to a known time interval. By noting which



channel registers, the operator can determine the time interval. Eldorado Electronics Co., Berkeley, California.

Circle No. 168 on Inquiry Card

WHICH SEAL WILL SOLVE YOUR PROBLEM?

Seals drawn to same scale.				
Type of Seal	**Standard**	**Modified**	**Bellows**	**Shaft Surface**
Pressure (PSI)	1000	500	250	75
Speed (FPM)	15,000	15,000	15,000	15,000
Temperature (°F)	350° to 450°	—360° to 350°	—360° to 700°	500° to 700°
Uses	Fluids including aviation fuel, synthetic lubricants, etc.	Rocket motors, HNO_3, H_2O_2, NPN, LOX, Ethylene Oxide	Applications calling for all-metal, high temperature sealing	Sealing gaseous mediums in a minimum amount of axial space
Send for	Bull. #7	Specially enginered	Bull. #18	Bull. #19

CAUTION: Maximum conditions indicated for each type do not necessarily imply that all are available in a single seal. Sealol engineers will gladly recommend the seal best suited to the operating conditions of your particular application. Write today . . . no obligation, of course!

SEALOL CORP
484 Post Rd., Providence 5, R. I.

SEALOL

FOR MORE INFORMATION CIRCLE 16 ON INQUIRY CARD

MICROSECOND PHOTOGRAPHY

Magneto-Optic Shutter: Stopping Fast-Transient Events

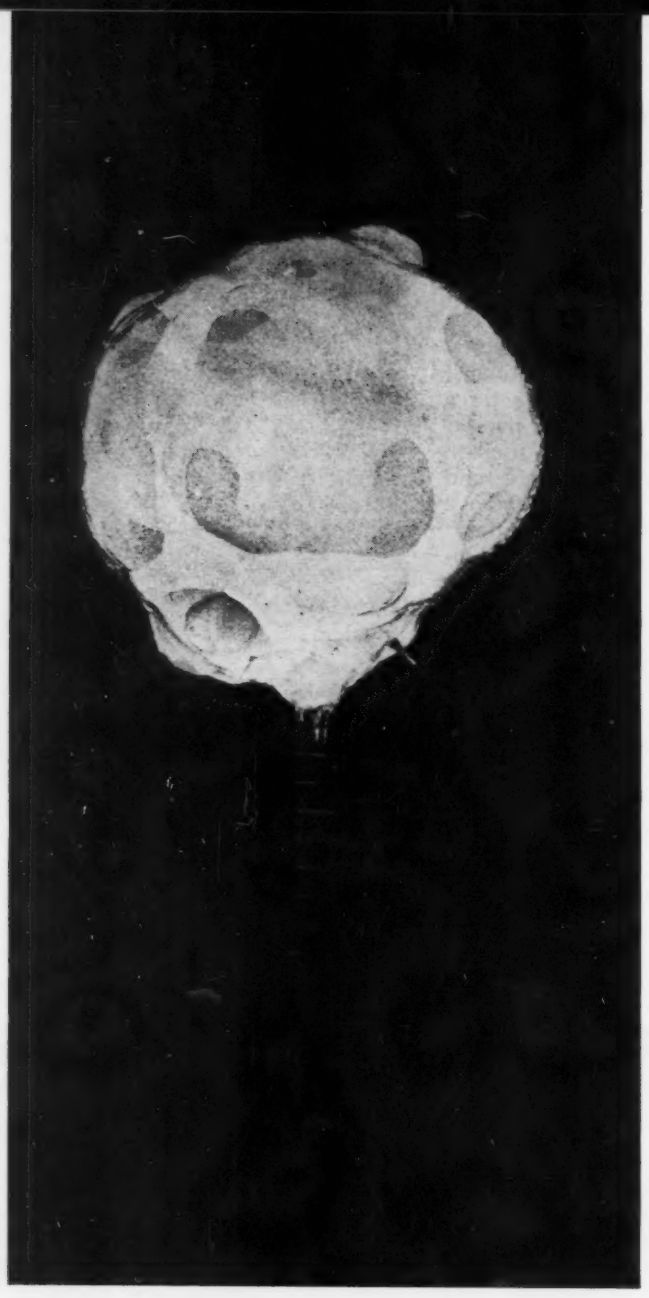
Fast transient events—such as, flame fronts, high velocity shock waves and high explosives—can only be stopped with extremely short exposure times, calling for a shutter whose speed of operation is not limited by mechanical moving parts. One type of shutter with this advantage is the magneto-optic shutter incorporated in a Rapatronic Camera (from rapid action electronic shutter) designed by Edgerton, Germeshausen & Grier, Inc., of Boston, Mass.

The over-all design called for multiple objectives:

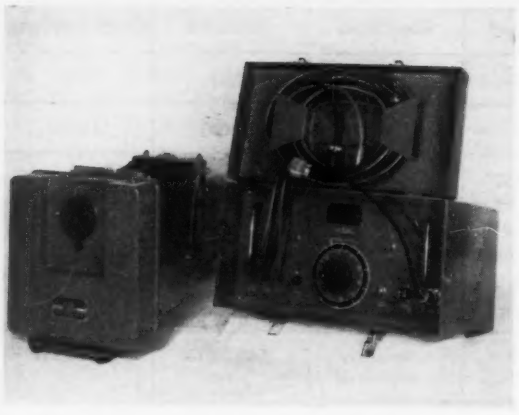
- Short exposure time
- Wide viewing angle capable of accommodating the usual photographic recording methods
- Large ratio of open-to-closed light transmission
- High resolution of the optical image
- Triggering system of an electrical nature where photo-electric signals could actuate the shutter.

E. G. & G.'s engineers state all of these objectives were realized in the shutter and control circuits of their camera. The physical arrangement of one type of magneto-optic shutter—the simple single element type—consists of two polaroid discs in a crossed position so that no light is passed. Between the polaroid discs is a glass element or other material that rotates the plane of polarization as a function of the magnetic field strength. For a shutter of practical dimensions the magnetic field strength for complete opening is very high.

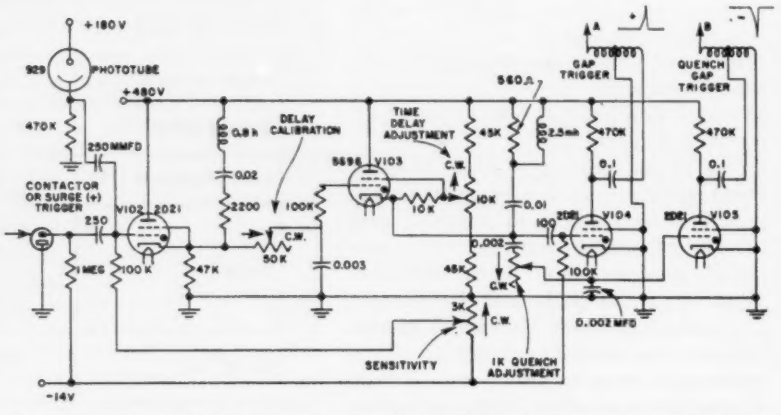
One practical method for obtaining such large field strength is by the condenser discharge method. Here,



Frozen fireball is a four microsecond exposure of an atomic explosion taken with the Rapatronic Camera. The fireball is shown some time after initiation but before it has consumed the power of the guide wires and before it has hit the ground.



Complete camera consists of the shutter unit on the left and the power supply unit on the right. A black disc on the camera unit contains the magneto-optic shutter with its fixed and variable polarizers. Housing on the right contains the low-inductance high-voltage circuitry that produces the short duration high-peak magnetic pulse that rotates the plane of polarization within the optical element and opens the shutter.



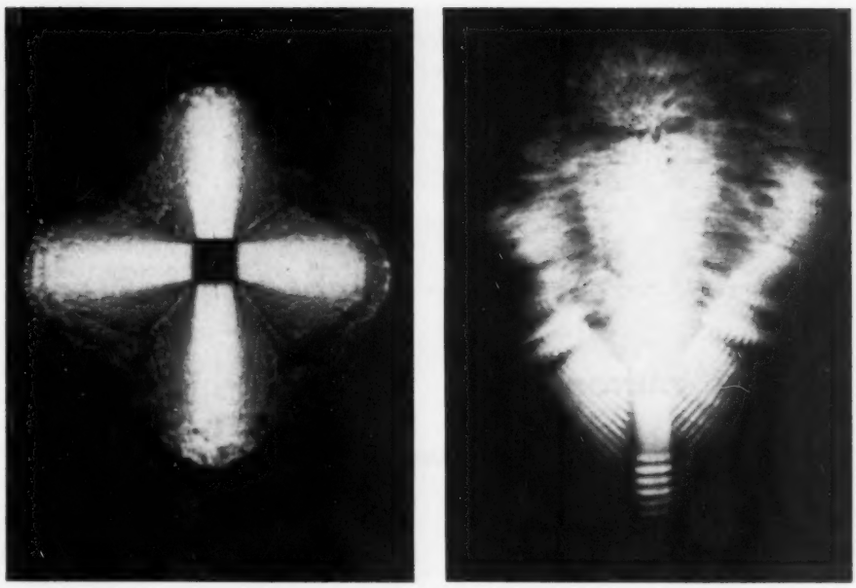
Trigger portion of the circuit is usually a photo-electric tube (marked 929 in the upper left) although a "make" circuit or a positive voltage pulse is equally effective. The flash of light from a subject illuminates the photo-cell creating a voltage pulse which trips the thyratron (V102) and the delay RC network. A dial on the unit controls the resistance (50 K variable) of the RC coupling portion of the circuit. Pick-off thyratron (V103) triggers after the time delay as determined by the pick-off voltage on the adjustable resistor (10K). Coil "A" exciting thyratron V104 triggers instantaneously with V103 followed in about 0.75 sec by V105 that triggers the quench gap and coil "B".

electrical energy is stored in a capacitor at high voltage so that it can be rapidly discharged into the coil around the optical element whenever a signal is received.

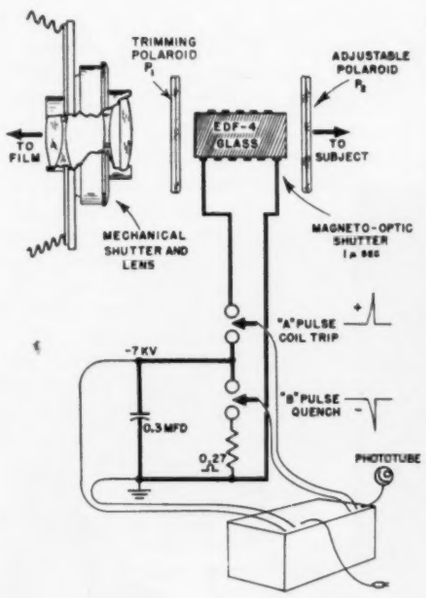
The camera has been applied to the solution of a series of problems in which the subject is self-luminous, permitting two possible methods of approach. One method is the use of the self-luminosity for producing the exposure. A second use of the shutter is to exclude the light from a luminous subject until light from an electronic flash tube illuminates the subject for a photograph. The camera is designed such that it can be used for either case.

E. G. & G. believes that the one-microsecond magneto-optic shutter with photo-electric triggering time delay circuits provides a convenient new field research tool for the explosive engineer and scientist. With long focal-length optics, excellent resolution of explosions in space can be obtained at a safe distance without the necessity of elaborate protection. Shutter synchronization by means of light from the explosion is most convenient since no electrical or mechanical connection to the previous explosion is required.

Circle No. 102 on Inquiry Card



Left photograph is an end view of the explosion of a square stick of Pentolite, three-quarters of an inch on a side and six inches long. Photograph on the right is the same subject taken from the side with the shutter undamped, accomplished when the quenching gap is prevented from firing. One method of accomplishing this is to remove the thyratron V105 (see circuit diagram). If the quench gap does not operate, then the current through the shutter coil will oscillate at the natural frequency of the circuit consisting of the capacitance and the coil inductance. The shutter does not depend upon the polarity of the current, therefore the shutter opens twice per cycle. Frequency is about one million times per second.



Polaroid discs, P_1 and P_2, are crossed with an extra-heavy flint-glass cylinder in the center. Current in the coil sets up a magnetic field in the glass cylinder that rotates the plane of polarization of the light, allowing transmission. The two-gap circuit excites the shutter coil for a half cycle. The A pulse coil initiates the discharge of the 0.3—μf capacitor into the coil around the glass element. The B pulse coil triggers the quench air gap which short circuits the main capacitor into a damping resistor after a half cycle of operation. In this manner the energy in the circuit is removed so that the capacitance and the inductance will not oscillate.

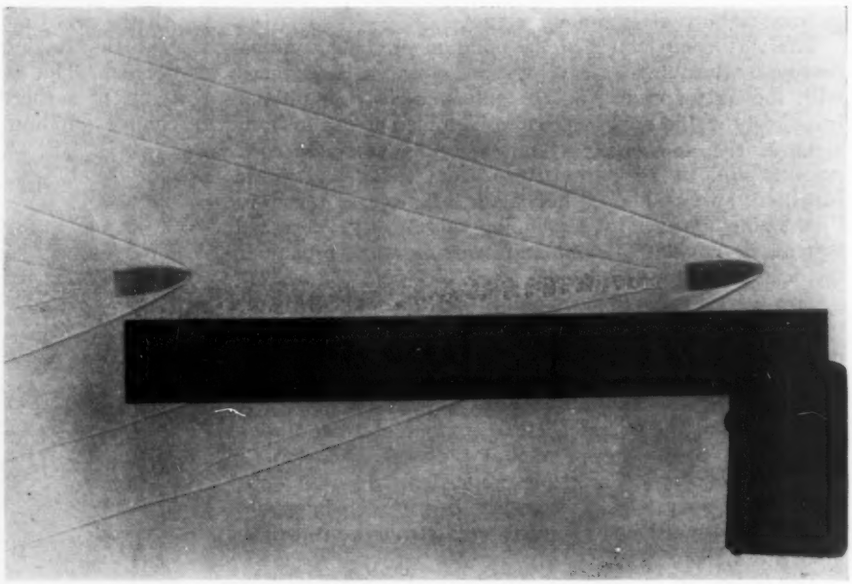


Illustration indicates how camera was used to stop a bullet twice. To the left a 0.220 caliber bullet is crossing the zero mark on an ordinary six-inch ruler. To the right it has reached the five inch mark. The exposures were made at one five-millionth of a second apiece with an interval of 100 microseconds between them. Shock waves, invisible by ordinary photographic methods, are clearly displayed here by a silhouette technique. Indistinct pattern resembling a smoke train is caused by the low pressure vortices or heated air filling in the "hole" left by the speeding bullet.

SYSTEMS OF COMPONENTS

STAFF COLUMNIST

Sidney A. Davis

Consulting Electromechanical Engineer

DAMPING FACTORS

ENTOMOLOGY IN DESIGN

Design of a complex control system is often so mathematical that the system designer is forced to think in terms of differential equations instead of actual hardware. Thus, a servo motor becomes

$$\frac{Kv}{p(1+pTm)};$$

an amplifier, K_a; and so forth, with neat little inscribed boxes to represent each of these components in the functional diagram. As the system gets bigger, a box may come to represent an entire servomechanism or computer whose complete behavior is "described" by the transfer function. This wonderfully convenient representation has permitted design engineers to combine boxes to form the greatest variety of complex systems.

The very compactness of the notation presents a danger, however. Resulting ease of system synthesis, particularly with the aid of electronic computers, belies the ultimate complexity of the final hardware. The danger lies in losing sight of the performance limitations of the system components and of their departure from idealized transfer function representation. Repeated instances of extensive time being applied in *developing* an already "designed" system, de-bugging it, and getting it to work reliably in the field illustrate the danger.

This narrowness of viewpoint and consequent poorer coordination among engineering sections may very well lead to expensive and time-consuming redesign and trouble shooting in the later phases of a major development program.

Many of the problems that arise from abstract designs are elementary in conception, but they can still result in delay and expense. Sometimes re-evaluation of an entire segment of a system is necessary because of impossible component requirements unwittingly spelled out by the system designer.

The following paragraphs describe some actual mistakes resulting from too limited a view in system designs. In all instances, limitations in the ability of a component to do the job and poor understanding of the non-ideal features of these components have resulted in heartache for the design engineer.

SYNCHRO CHAIN

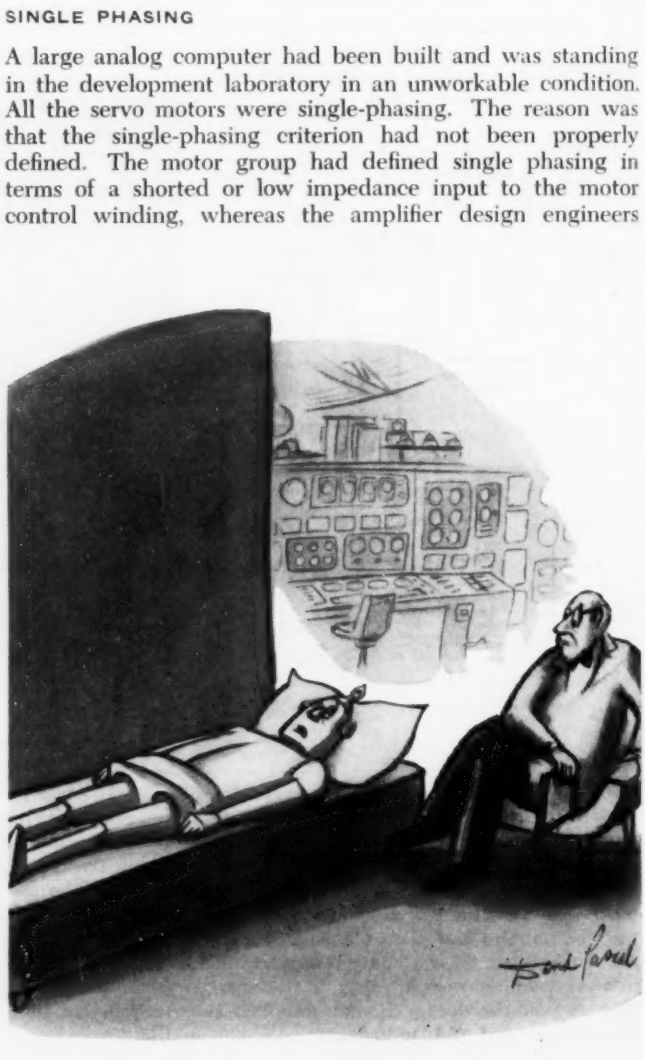
A 60-cycle synchro system was designed using miniature 400-cycle components. To avoid saturation, the components were run at reduced voltages. The system was very complex with many synchros in series and parallel groups excited by the same transmitters. The system was easily designed on paper, the block diagram showing an arrangement of labeled circles interconnected by single lines. When the system was assembled, however, it did not work! Phase shifts were up well beyond 90 degrees rather than the approximately 0 degree required from the output of the control transformers. The output signals contained excessive residual voltages. Signals were so badly attenuated in the series sequence of synchros that gain was inadequate. Tedious analysis leading to replacement of synchros and rephasing of networks finally yielded desired performance. And all this was required on finished compactly assembled hardware sitting in the development laboratory instead of the shipping department.

MAGNETIC AMPLIFIER

A system was designed with magnetic amplifiers feeding the servo motors. The amplifiers were of an unusually compact design. However, torque from the servo motor proved to be inadequate, and overheating also existed. An investigation showed that amplifier and motor specifications had been written by different groups which did not communicate adequately with one another. The amplifier developed a second harmonic signal of full voltage, even with a null signal at its input. This second harmonic caused the motor overheating. When an error signal was developed, the corrective output appeared as merely a "distortion" of the second harmonic output. Achieving specified performance in the presence of this highly nonlinear condition was much more of a problem than had been anticipated.

SINGLE PHASING

A large analog computer had been built and was standing in the development laboratory in an unworkable condition. All the servo motors were single-phasing. The reason was that the single-phasing criterion had not been properly defined. The motor group had defined single phasing in terms of a shorted or low impedance input to the motor control winding, whereas the amplifier design engineers



developed a unit with quite a high output impedance. The most unfortunate part of the situation was that the hardware was so compactly packaged that there was almost no opportunity for inserting a tachometer or other correcting device. Solving this single-phasing problem and making the computer work was a long drawn out affair.

IMPOSSIBLE SPECIFICATIONS

In one instance, a computer had been designed around an integrator whose required accuracy was 0.05 percent! While manufacturers' catalogs did indicate in their broad specifications that an accuracy of 0.05 percent was available, more detailed examination of those specifications revealed that the accuracy referred to was only one portion of the total error which might be generated by the integrator and occurred only under a limited set of conditions. When the basic computer design is based upon an unrealistic accuracy requirement, the problems are especially difficult to solve. In this instance, it was necessary to go to an entirely different kind of integrator with a complete redesign of the mechanical packaging in order to achieve the required results.

DIELECTRIC PROBLEMS

A system was designed around a motor-amplifier combination of great compactness and ruggedness. By means of ingenious circuit simplifications, it was possible to eliminate many of the components normally required in the amplifier. However, early systems in the field showed repeated failures due to burn-out of the servo motor windings. After a good deal of investigation it was discovered that the simplification of the amplifier had resulted in something like 750 peak volts being developed between motor windings. Redesigning the motor insulation system and putting it into production was a major engineering job. With the entire computer designed around this motor-amplifier combination, the investment in the solution of this problem was tremendous. Ultimately, however, the problem was solved and a particularly good computer was produced.

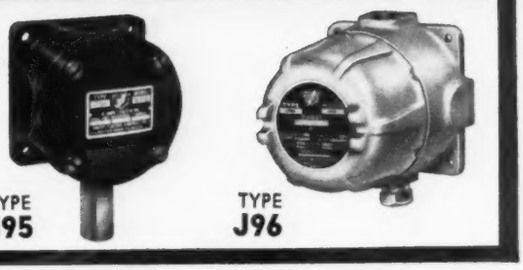
Many additional instances of this type situation could be described. Too often, servos are designed with such high loop gain that it is almost impossible to eliminate buzz. Performances are frequently based upon idealized single time constant elements when a whole host of residual time constants actually enter the picture and constitute the true limit to the ability of the system to perform.

The solution to the above problem is obvious. The system designer must familiarize himself with the details of component behavior. He should stop in at the components laboratory and talk to the engineers and maybe watch a few tests. He should make a point of familiarizing himself with the R & D problems of making his system work. On the other hand, the components man can describe his components in terms familiar to the systems engineer. The component designer (like most engineers) is a notoriously bad report writer, which means that his carefully written masterpiece may lie unread in the designer's file cabinet. Magazines, such as the one you are now reading, try to fill in much needed liaison by covering both *systems* and *components* in one editorial program. The design problems and tutorial articles covered in these pages may profitably be read by *both* component and systems engineers.

Probably a remarkable monetary saving and greatly increased efficiency could be achieved in the new system development if a maximum awareness of hardware limitations was aimed at early in the program, so that the prototype finally put together would be one step closer to the ultimate working system. END

HAZARDOUS CONDITIONS? J95 / J96

Use UE Explosion Proof PRESSURE-VACUUM CONTROLS



The Types J95 and J96 Pressure-Vacuum Controls are designed for applications in hazardous locations where explosive vapors or gases are present and close on-off differential control is required. In both units, pressure settings are uncalibrated and adjustment is made by an internal nut.

Adjustable Range . . .	J95 — Various ranges between 0 and 500 psi limits. J96 — Various ranges between 0 and 180 psi limits.
Switch Differential . . .	J95 — Factory pre-set for any differential between 2 and 30 psi. J96 — Factory pre-set for any differential between 3" W.C. and 2 psi.
Switch Ratings	Up to 15 amps. at 115 or 230 volts A.C. 20 amp. A.C. or D.C. switches also available.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
Maximum Pressure . .	J95 — Up to 600 psi. J96 — Up to 180 psi.
Electrical Connections .	J95 — Lead wires attached to screw type terminals on switch via ½" NPT opening. J96 — Lead wires attached to terminal block via ¾" NPT opening.
Pressure Connection . .	Via a ¼" female NPT connection.
Enclosure	J95 — Cast iron with a gray, baked-enamel finish. For use in Class I, Groups C and D locations. J96 — Cast iron base and aluminum cover. For use in Class I, Group D; Class II, Groups E, F, and G; or Class III locations.
Mounting	Surface-mounted by four corner holes with clearance for ¼" screws.

UNITED ELECTRIC ***manufactures a complete line of temperature, pressure, and vacuum controls. For information on modifying standard units or providing custom-built units, consult a UE application engineer. For additional data on the Types J95 and J96, request new literature available.***

UE® United Electric Controls COMPANY
85 SCHOOL STREET WATERTOWN, MASS

FOR MORE INFORMATION CIRCLE 17 ON INQUIRY CARD

FIG 1—Photo illustrates the Digitape cabinets that control a line of machine tools. The master control panel at extreme right starts and stops tape readers, machines and transfer line. Next toward left, four tape readers feed tape through sensitive metal fingers that "feel" the punched information. To the left of the tape readers, the control cabinet for the boring machine takes information from the tape readers, converts it into instructions for machine movement and operation. Behind research assistant Norman Wells is the control cabinet.

FIG 2—Operated by the Digitape electronic controls of Fig. 1, the milling, drilling and boring machines (left to right) pass parts along automatically after each machining operation has been completed. These machines, in conjunction with their control cabinets, permit "Detroit" type of production techniques for small job lots that constitute most of the machining done by American industry.

NEW MACHINE TOOL SYSTEM

Punched Tapes and Transistorized Digital Computers Translate Blueprints into Machined Parts

What was described as "the nation's first all electronically controlled line of machine tools," operated from punch tapes and controlled by transistorized digital computers was revealed last month by the Hughes Aircraft Company.

Rollin M. Russel, Hughes Vice President and Chief Executive of their Products Group, stated that the company's Digitape electronic control has been linked with a milling machine, a drilling machine and a boring machine to make available for the first time the economies of "Detroit" type mass production techniques in the area of small lot production that now constitutes most of the machining done by American industry. Russel believes that his company has the nucleus of the nation's first electronically automated factory. "The ability of the Digitape numerically controlled line to shorten the time between engineering release and production of parts, and the ability to make engineering changes without sacrifice of production rates, will," he said, "be of very substantial importance in crash development programs such as the United States now has under way.

"Single machine tools have been electronically controlled in the past, but this is the first successful application of automatic electronic controls to a series of machine tools working on successive operations and, in fact, making a variety of parts at the same time," Russel said. Changes in operations may be introduced or production may be started on new parts simply by changing punch tapes and without stopping the machines, he explained.

DESIGN DETAILS

The integrated machine line with Digitape controls is constructed on the building block principle. Both machines and controls fit together as blocks in any desired number and arrangement to provide the greatest production savings for the type of parts to be machined. The line may be added to and rearranged from time to time and will be still capable of operation from a single tape for each type of part. Translating the system brings different cutters in sequence on the

piece to be machined. Some cutters are in the magazine of a single machine, others are associated with different machines.

The milling machine is arranged such that the head can move in three axes and the work which is secured to a pallet may be rotated 360 degrees. Feed speed is controlled electronically in all axes. The ways are clamped before cutting to insure a good surface finish.

The boring machine has a boring bar that is set to proper dimension automatically by the signals read from the tape. It has two spindles to cover either different ranges of bore holes or to provide for having a milling cutter inserted in one spindle to make the machine tool more versatile.

The drilling machine has a magazine in which various size drills and taps can be stored. Each drill has its own drill bushing which is extended when the drill is extended. This eliminates the need for separate drill boxes or plates for different parts. It insures accurate chordal dimensions because the drill can't walk or bend; it is held rigidly by a bushing at the point where the drill enters the work. Each tap has its own lead screw to insure accurate thread cutting. When a drill or tap breaks, a safety is actuated causing the drill or tap to be automatically retracted.

The drilling machine is equipped with a unique fast-operating tool change mechanism that accommodates twenty mixed drills, reamers, taps, boring tools, and other accessories. Optimum speeds and feeds are automatically selected as part of the programmed information on the machine controlled tape. Flexibility built into the controlled automated line of the machine tools permits simultaneous operations on an "inter-mix" of work pieces. For example, it is possible, by inserting four different tapes in the three-machine line, to machine four entirely unrelated parts. This is the most practical application of the line insofar as tooling cost is concerned—only one work holding fixture would be required for each different part. To machine a quantity of an individual part on the line, four identical tapes would be needed. Because of the relatively low set-up time, a few parts, in any sequence, can be run through the line almost as inexpensively as several hundred parts.

ADVANTAGES OF THE SYSTEM

Because of its automatic nature, the line requires only one operator. Tapes can be punched by a typist after only a few hours of special instruction.

FIG 3—William Wagenseil, Hughes' director of industrial systems and controls, points to tapes that produce the parts illustrated. Hughes' new system can simultaneously produce all the parts illustrated above.

FIG 4—Part of the new automation technique is a metal bar. The white stripe on the bar is actually a series of finely etched lines, 500 to the inch, that small cylinder pick-up head counts to position machine cutting edges so precisely that machine parts are accurate to 0.001 inch. Principle of counting method is the same as used by magnetic underwater mines that are activated by changing electromagnetic field.

The required precision is built into the line and the controls, thus requiring less operator skill. Set-up operation is virtually eliminated saving labor and time. Tooling on the average is 50 percent less, saving tool design and tool production time, thus shortening time between engineering drawing release and actual production. Spare parts and reorders may be quickly and economically produced at a time subsequent to the main production run with the same high quality and uniformity of the original, eliminating costly inventories.

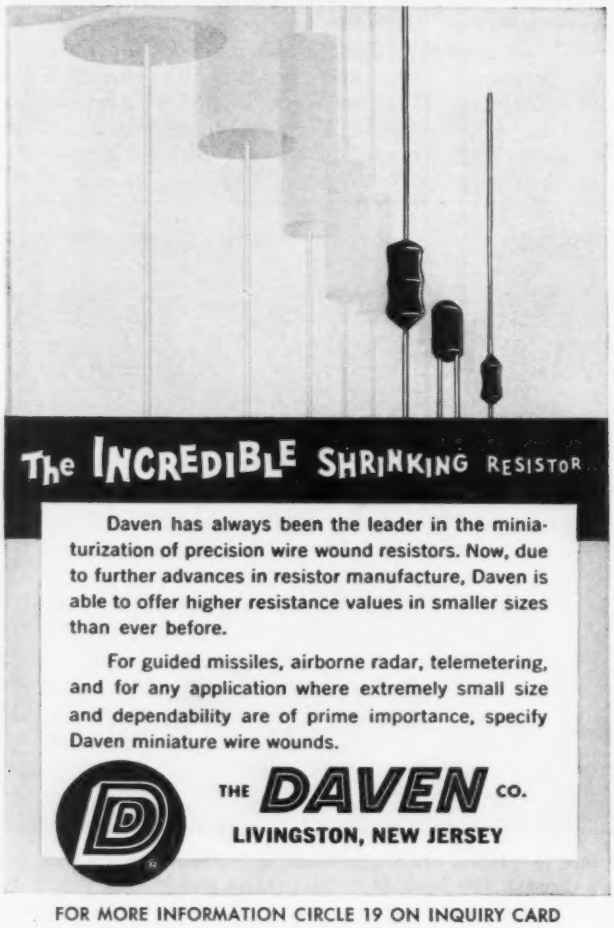
Initial economic studies by Hughes indicated that this machine tool line combined with the controls would be useful not only to Hughes but to the metal working industry in general and especially where small quantities of parts are produced at one time. Production designs of both the controls and the machines developed by Hughes in conjunction with Kearney & Trecker Corporation, are expected to be ready for delivery during 1958.

Circle No. 174 on Inquiry Card

FIG 5—All information sent to milling, drilling and boring machines by the Digitape control system flows through this bank of contact relays and blinker lights.

push-pull
CONTROLS
Compression & Tension Type
Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.
Three Types:
1. Light Duty—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. Heavy Duty—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
3. Extra Heavy Duty—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.
Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD 58.
SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

FOR MORE INFORMATION CIRCLE 18 ON INQUIRY CARD


The INCREDIBLE SHRINKING RESISTOR
Daven has always been the leader in the miniaturization of precision wire wound resistors. Now, due to further advances in resistor manufacture, Daven is able to offer higher resistance values in smaller sizes than ever before.
For guided missiles, airborne radar, telemetering, and for any application where extremely small size and dependability are of prime importance, specify Daven miniature wire wounds.
THE DAVEN CO.
LIVINGSTON, NEW JERSEY

FOR MORE INFORMATION CIRCLE 19 ON INQUIRY CARD

RESEARCH

STAFF COLUMNIST

Jesse E. Hobson

Jesse E. Hobson is Vice President of the United Fruit Company

RESEARCH FOR LONG RANGE PLANNING

We hear a great deal today about company long-range planning. In the business press and throughout all of the management media, "LRP," the familiar diminutive, is used frequently and discussed prominently. Many companies have established formal procedures and organizations to develop master plans for the future; conferences are held to discuss and exchange ideas about planning techniques; research organizations and universities are devoting increased study to the formulation of plans; professional planners are emerging.

Management generally has become quite aware of the necessity for planning guides to future actions. Throughout the business world LRP is a formal concept of increasing stature and an operational concept vital to sound company growth. Planning influences and integrates products, processes, personnel and profits. In the new LRP context it is all-inclusive.

The very first requirement of a long range plan is that it rest on an objective and critical appraisal of the company itself, its assets, weaknesses, strengths, objectives and problems. Usually these questions are no easier to answer and no more difficult to formulate than is the most basic inquiry itself: what is the real business of the company? An accurate definition is absolutely essential to successful planning.

For example, is a ceramics company in business to sell clay? or is it in business to supply market needs for pipe, chinaware and structural materials? The answer will be the keystone to determination of long range plans. From the answer will come decisive, and perhaps unexpected, new evaluation of the company's assets, operations and, eventually, goals. Only in the perspective of a company's reason for existence can its strengths, its shortcomings and its potential be fully and properly evaluated.

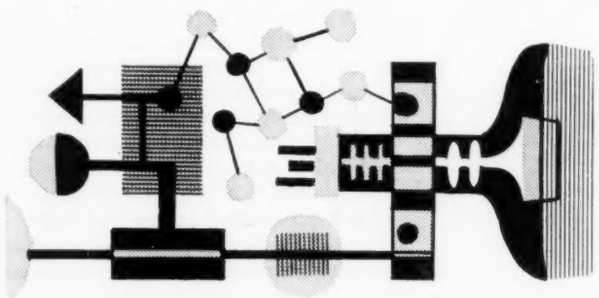
The business of the United Fruit Company, my own company, is tropical agriculture. True enough, we are in the shipping business with our Great White Fleet of sixty vessels. But fleet, piers and docks are necessary adjuncts to our real business of growing tropical agricultural products and transporting them to market areas. True enough, we are in the communications business with Tropical Radio Telegraph Company carrying more than half of all commercial messages between the United States and Central America. But again, Tropical Radio is another necessary adjunct for maintaining communications with our ships at sea and our plantations in eleven Latin American countries. True enough, we are in the banana business—an endless belt would have to travel 120 miles-per-hour every second of the year to carry all the Chiquita banana fingers we sell

each year in the United States, Canada and Europe. But although bananas are far and away our principal product, the real business of the United Fruit Company is in managing more than two million acres of land in tropical countries with the background of many years of agricultural experience.

The long range plans for United Fruit Company must be based on this concept, including major emphasis on bananas. Thus we are being led, through our long range plans and by a definition of our business, to more effective use of lands, perhaps to crop diversifications and to new ventures which will maximize our assets in land, ports, ships, communications and agricultural know-how.

This primary question of what our company really is may not be an easy one to answer. For many other companies it is even more difficult. Is a milling company in business to process and sell wheat and grains? Or is it in business to supply breakfast cereals and other items for the grocery shelf? The answer should determine the future course of the company, should indicate where its capital should be invested, where its manpower should be concentrated, and where its research should be directed.

Behind each of these basic considerations lies an essential research effort: research to get the *facts* about the company's business, about its weaknesses, strengths, problems, competitive position and opportunities. Intuition, hunch, subjective evaluation can lead to unsound conclusions, and



there's not much margin any more for wrong hunches. Partial answers, fuzzy answers, or plain wrong answers dilute a company's assets, reduce its earning potential, worsen its competitive position, misdirect its research and frustrate its staff.

Long-range planning is an exacting exercise. It requires vast knowledge of and familiarity with company finances, operations and personnel. It will raise many questions hitherto unasked, and will call for much new, accurate and well-organized data about the past and present as well as about the future.

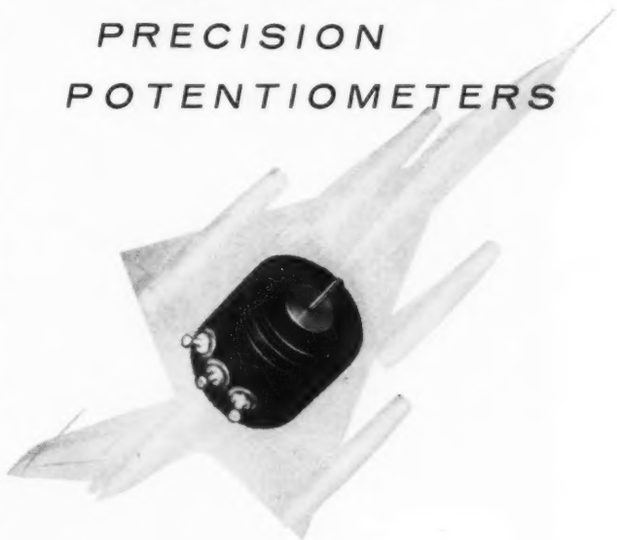
Since projections can be no more substantial than the data and experience on which they are based, research is again a key factor. For without trustworthy research investigations into technical and financial matters, operations, marketing and optimum use of resources, LRP can be little better than a hunch.

Research plays three primary roles in the planning function. 1) It is the source of facts on which planning is based. 2) It is the tool by which the facts are evaluated and coordinated. 3) It offers means to the solution of technical, economic and human problems by which errors can be corrected, weak spots strengthened and assets maximized.

Research is the heart and head of long-range planning.

now . . .

PRECISION
JEWEL BEARINGS
help to produce
PRECISION
POTENTIOMETERS



Waters LO-TORK Potentiometers with Bird Jewel Bearings are used on U.S. Air Force Supersonic bombers.

Here's how Bird Sapphire Jewel Bearings helped a prominent manufacturer of electrical instruments to make a major product advance.

Waters Manufacturing, Inc., manufacturers of precision potentiometers, were asked to design a miniature potentiometer with minimum torque and reliable operation when operated in a contaminated fuel mixture. The result was the new Waters LLT ⅜ LO-TORK potentiometer with jewel bearings — an entirely new concept in miniature potentiometers.

Bird Sapphire Jewel Bearings are specified in the new Waters LO-TORK Potentiometers because they provide higher accuracy and longer instrument life. Waters LO-TORK Potentiometers with Bird Sapphire Jewel Bearings stand up under even the most rugged accelerated corrosion tests conducted by the Armed Forces. In fact, Waters LLT ⅜ potentiometers are now being used in fuel flow meters where they must withstand the rigors of jet fuel.

Bird Precision Jewel Bearings have been used by the foremost manufacturers of electrical, aircraft and timing instruments and recorders. They are available in a wide range of standard types, sizes and complete assemblies — or custom-built to your specifications.

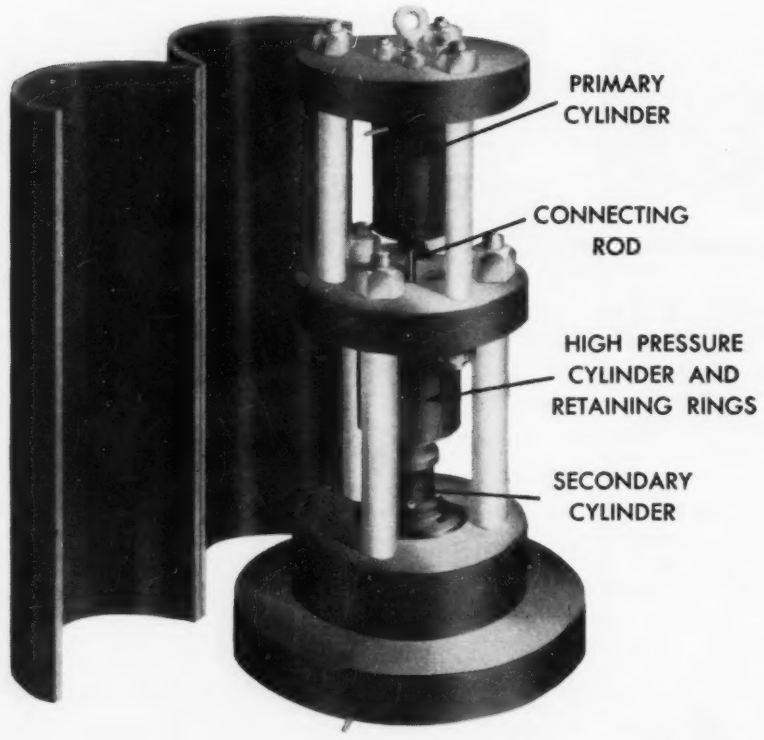
If your product design calls for jewel bearings, our engineering staff is at your service. A request on your letterhead for Bulletin 100-9 will receive our prompt attention.

Richard H. Bird & Co., Inc.

1 Spruce Street, Waltham 54, Mass.

SAPPHIRE & GLASS JEWELS • PRECISION GLASS GRINDING
JEWEL MOUNTING & ASSEMBLY • SAPPHIRE STYLII

FOR MORE INFORMATION CIRCLE 20 ON INQUIRY CARD



Parabar high-pressure list unit with guard removed. The unit is about 4 ft. high and 2 ft. in diameter.

RESEARCH EQUIPMENT

Superpressure Made Easy

Extremely high pressures have been used for some time to investigate and study the basic properties of materials. The lattice structure, or inter-atomic distance of materials change under such pressures causing polymorphic transition and differences in electrical and other characteristics.

A device called Parabar for obtaining high test pressures has recently been made available commercially by Nucor Research, Inc. of Ferndale, Michigan. Two units are being manufactured—one for 30,000 atmospheres in a chamber ½ inch in diameter by 10 inches high with electric leads into the chamber, and the other for 50,000 atmospheres in a ½ cubic centimeter chamber.

According to Professors P. W. Bridgman and William Paul of Harvard, the problems facing designers of very high pressure equipment are unusual and for the most part have been solved by trial and error. Originally, the tool steel used for pressure cylinders, or bombs, was hardened, but hardened bombs cracked under pressures above 10,000 atmospheres. Half-hardened steel didn't crack but the metal moved up to its elastic limit and then underwent a plastic flow that became a permanent set. However, at the same time this plastic flow work-hardened the steel. Present designs generally make use of this work-hardening effect.

To take advantage of this effect, Nucor engineers formed the cylinder in three operations. A small bore and piston are used first and the pressure is brought to the amount for which the equipment was designed. The cylinder is then reamed 0.010 inch larger, a new piston is fitted and the procedure is repeated. Finally, the cylinder is reamed out to the final diameter and the work hardened material with the help of retaining rings is able to take the designed pressure without further plastic flow of the metal. However, if this pressure is exceeded the plastic flow occurs again. Carboloy can be used for small, higher pressure units but it is very difficult to machine as a cylinder. It is usually used as part of the piston.

The pressure medium which transmits pressure from the piston to the tested material can be a gas, a fluid, or a plastic solid like lead. The gas or fluid transmits even pressures while the plastic solid may be made to concentrate on a specified area.

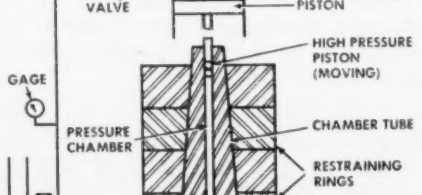
When gas is used, as it usually is for high temperature, high-pressure work, it is already at a very high pressure when it is introduced into the bomb. A combination of nitrogen and argon is the commonest medium. An interesting design side-light here is that the gas is introduced at 18,000 atmospheres through a ⅛-inch-outer-diameter stainless-steel tube with an 0.025 inch bore, which shouldn't be able to stand half that pressure—but does.

Most fluids freeze at very high pressures. Pentanes have been found not to, and although they cannot be used at high temperatures they, especially isopentane, are about the best for straight pressure problems. Contrary to general belief, fluids compress considerably under high pressures. Fifty percent decreases in volume are not uncommon.

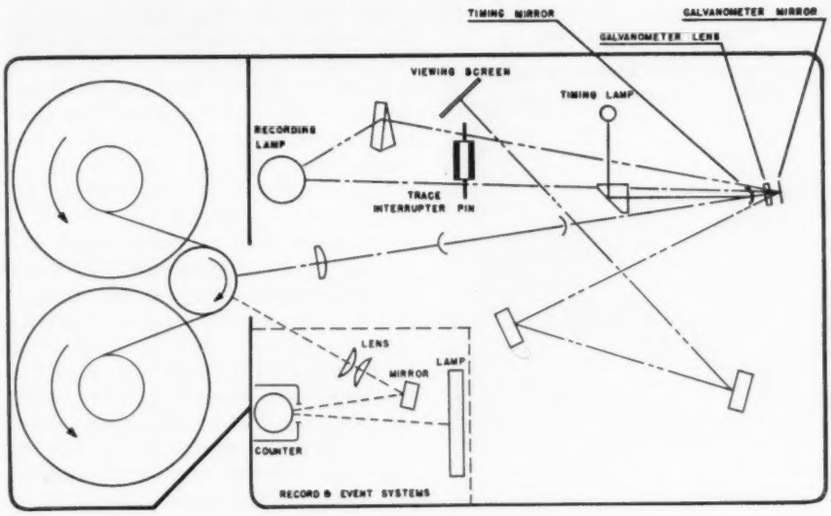
The use of a plastic solid as a medium is a relatively late development. Localized pressures with this method go into the hundreds of thousands of atmospheres and information may be derived from the pressure gradients existing in the tested material.

The possible uses for high pressure equipment are extremely varied. Basic research under high pressure conditions is being carried on to investigate electrical properties of semi-conductors and solid state devices. Light waves through NaCl at 100,000 atmospheres have been studied at the University of Illinois. Synthesis of chemicals and petroleum products at high pressures has been given considerable attention.

Circle No. 103 on Inquiry Card



Schematic drawing of Parabar, showing principal operating parts. 30,000 atmospheres pressure in the high pressure cylinder with ½-inch-diameter piston are obtained by hand pumping oil to approximately 9,000 pounds per square inch into the primary cylinder with a 3½-inch piston. Pressure applied separately to the piston of the secondary cylinder forces the high pressure cylinder with a conical outside diameter into retaining rings which give added strength.



OPTICAL DIAGRAM

5-122 RECORDING OSCILLOGRAPH

TIMING LINE
GALVANOMETER SCAN TRACE
GALVANOMETER TRACE
RECORD & EVENT NUMBER

HI-TEMP TEST RECORDER

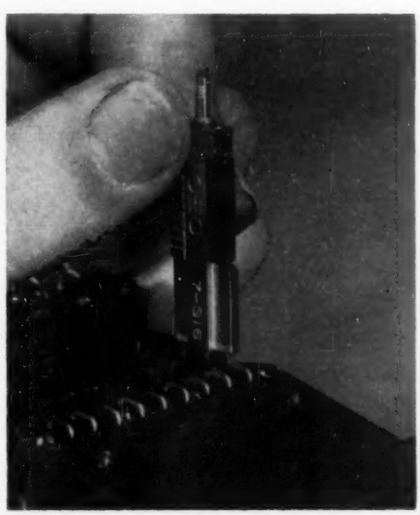
New Developments in Recording Oscillographs for Aviation Testing

The photographic recording oscillograph is a most versatile instrument for dynamic testing. It electronically amplifies input signals from transducers such as strain gages, accelerometers, vibration pickups, thermocouples and pressure pickups and transmits these signals to supersensitive galvanometers where their deflections are recorded as beams of light on moving, sensitized photographic paper. It can record as many as 50 simultaneous items of test data, permitting study of all phenomena in their true relation to time and to one another.

Consolidated Electrodynamic Corp. has developed a new oscillograph, type 5-122, said to be the first instrument designed specifically for flight-test recording at high temperatures. Explosion-proofed it will operate from −65°F to +250°F at altitudes up to 120,000 ft. It withstands a 15-g steady force in any of the three planes without deterioration of performance and a shock of 30 g's for 11 milliseconds without damage to the instrument or its mount.

Consolidated has also developed an explosion proof, crash-resistant magazine, to fit their Type 5-119 Recording Oscillograph. Housed in a ductile-iron casting, surrounded by a stainless-steel shell, this magazine will withstand a 400-g shock and a 2000°F fire. The space between the casting and shell is filled with foamed silicone resin to provide heat insulation. In addition, the outer shell is painted with fire-resistant

Consolidated Electrodynamics Type 5-122 Recording Oscillograph for high-speed, high-altitude flight work. Explosion-proofed, it will operate from −65°F to +250°F at altitudes up to 120,000 feet.



This is how a CEC galvanometer is inserted in the magnet block of a recording oscillograph.

That's the story of Boehme Fine Pitch Precision Gears. Hobbed to meet requirements that include up to ⅛" x 5" O.D. — 180 — 16 D.P. AGMA Precision #3.

Spur Gear Clusters

Worm Wheels

Spiral Gears

Spur Gear Clusters

Quadruple Thread Worms

. . . and when it comes to Boehme Precision Manufacturing Facilities

you'll find a whole new concept of design and engineering skills backed by experienced craftsmanship in the production of electrical, electro-mechanical and electronic products for automation and instrumentation.

Learn how Boehme can help you meet today's competitive demands. Send for descriptive literature, now — There is no obligation.

H. O. Boehme, Inc.

Designers and Manufacturers
Communication Equipment
Precision Electro-Mechanical
Apparatus Since 1917

915 Broadway New York 10, N.Y.

CIRCLE 21 ON INQUIRY CARD

Transistorized
3"x3½"x3 13/16"
Transformer cased

Power Supplies

Elasco's MINISOURCE power supplies, fixed or semi-variable, are designed for use with transistorized circuits, instrumentation, computer circuitry, as bias supplies, or any application where good regulation of low voltage is required. They are available for either 60 cycle or 400 cycle operation, for *any* voltage between 4 and 50 volts, and at current ratings between 50 and 500 ma:

INPUT: 105—125 V AC

REGULATION: better than 0.5%

RIPPLE: better than 0.5%

OUTPUT IMPEDANCE: less than 0.25 ohms, DC—100 kc

POLARITY: grounded or floating operation

TEMPERATURE: compensated from —30 to 65C

PRICE RANGE: $55 — $115 f.o.b. Boston

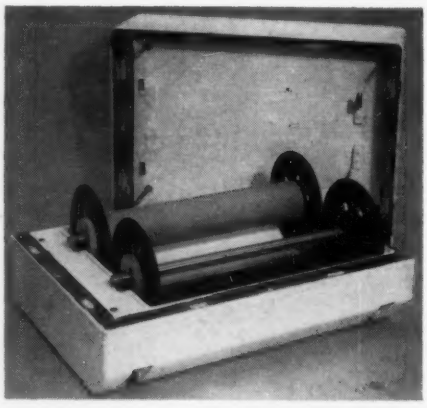
Send for complete catalogue

ELECTRONIC ASSEMBLY COMPANY, INC.

Five Prescott Street
Roxbury 19, Mass.

CIRCLE 22 ON INQUIRY CARD

paint which foams at about 300°F and forms a thick insulating layer.

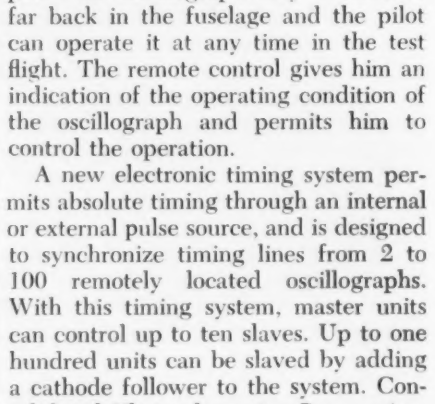


Consolidated Electrodynamics new Type 5-032 Crash-Resistant Oscillograph Magazine. Designed for flight-test recording, it will withstand a 400-g shock and a 2,000°F fire.

Another accessory developed by C.E.C. that makes the recording oscillograph more effective is a remote control which permits operation of the oscillograph from a distance. In an airplane the oscillograph may be located far back in the fuselage and the pilot can operate it at any time in the test flight. The remote control gives him an indication of the operating condition of the oscillograph and permits him to control the operation.

A new electronic timing system permits absolute timing through an internal or external pulse source, and is designed to synchronize timing lines from 2 to 100 remotely located oscillographs. With this timing system, master units can control up to ten slaves. Up to one hundred units can be slaved by adding a cathode follower to the system. Consolidated Electrodynamics Corporation.

Circle No. 214 on Inquiry Card



Miniature Predesigned Mechanisms and Components for Servos

A novel line of miniature predesigned mechanisms and mechanical components for the servo and instrument industries eliminates the need to design, detail, and fabricate mechanisms for many applications. A typical unit, which may be assembled in minutes from stocked parts, consists of 6 rotating shaft components, is 2⅞ inches in diameter, and is available in an almost unlimited choice of gearing and component configuration. Standard stocked components include truly miniature clamp-on gears, antibacklash gears, pin couplings, and slip clutches. These, in conjunction with a predesigned ball bearing gear plate assembly and 0.125 inch diameter shafts of various standard lengths, provide a versatile precision gear box with as many as six shaft extensions on either side. A complete mechanism is formed by assembling standard pre-bored component mounting plates to the gear box. All sizes of servo components are accommodated by means of pilot adapter rings. With this new apparatus the optimum in a new design can be readily attained by changing gear ratios, introducing antibacklash gearing, varying the components, and so forth. Once optimized, the unit may be shipped as deliverable equipment to fulfill contract commitments. It will meet the requirements of MIL-E-5400. Enclosures for the predesigned mechanisms are available in hermetically sealed and dust tight designs with plug-in or AN connectors. Precision Mechanisms Corp., East Meadow, N. Y.

Circle No. 166 on Inquiry Card

WORTH FILING

Special Fasteners

40-page Simmons Fastener catalog gives specifications, engineering drawings, applications, and installation information on the new Hinge-Lock and Spring-Loaded Link-Lock, as well as other special fasteners: Dual-Lock, Quick-Lock, Roto-Lock, Spring-Lock and the regular Link-Lock.

Source: Simmons Fastener Corporation
Albany 1, New York

For your copy: Circle No. 91 on Inquiry Card

WORTH FILING

Synchro Data Charts

Theta Instrument Corporation has compiled authoritative data into two wall charts for users of synchros and resolvers. One card accurately defines the important parameters designated on manufacturers' data sheets. The other designates the synchro and resolver windings at which null voltages may be found for various input connections and rotor angles.

Source: Theta Instrument Corp.
East Paterson, N.J.

For your copy: Circle No. 92 on Inquiry Card

RESEARCH

SPECTROSCOPY

Very High Frequency Radio Waves Used to Measure Behavior of Electrons

A recent and powerful technique in analysis, reported in the Industrial Bulletin of Arthur D. Little, Inc., is electron paramagnetic resonance spectroscopy—EPR for short. The EPR spectrometer uses very high frequency radio waves to measure the behavior of electrons in the substance to be analyzed; particularly, it is concerned with "unpaired" electrons, typical of the chemically active free radicals, which are important participants in both chemical and biological processes. Through EPR, we have already learned much new information about these free radicals, the report stated.

Electrons are responsible for most of the chemical properties of matter. The combinations of atoms that form molecules are numerous and complex but all result from interactions of electrons, following well-known principles. One such principle is derived from the fact that an electron carries a negative charge. Atoms of metals tend to lose their outer electrons and become positively-charged ions; non-metals like to add additional electrons and become negative ions. Through electrostatic attraction, the ions of metals and nonmetals combine to form many inorganic compounds, and the force that holds them together is called the ionic bond. Another principle, according to which two atoms share a pair of electrons, is the basis of the covalent bond, common among organic compounds. This bond results from electromagnetic interaction between the electrons. Both types of bonding involve electron pairing, and chemical combinations where electrons behave this way are usually stable.

UNPAIRED ELECTRONS IN FREE RADICALS

Neither one of these principles, however, applies to certain chemical combinations known as radicals. Most radicals are unstable under normal conditions. They cannot last long in the "free" state, and cannot be isolated or observed by conventional methods. Their instability results from the fact that one or more of the outermost electrons is unpaired. But the analysis of free radical behavior is essential to understanding many processes. The new EPR technique makes it possible to study them by considering the interaction of their unpaired electrons with magnetic fields.

Each unpaired electron, because of its rotation and its electrical charge, is like a small magnet. In a steady magnetic field, it will behave like a spinning top, and its axis of rotation will precess, or wobble, at a rate proportional to the strength of the steady field. Then, if an alternating magnetic field is applied, at just the same frequency as the electron's precession, the electron will absorb energy. Under proper conditions, the energy absorption, and the frequency at which it occurs, can be measured to a high degree of accuracy and to a sensitivity equivalent to one unpaired electron per hundred billion molecules. The equipment to do this operates in the microwave frequency range, and it is called the EPR spectrometer.

A group of unpaired, non-interacting electrons exposed to a constant magnetic field will produce a sharp resonance absorption at a well-defined frequency; this occurs in the case of some unusually stable, complex, organic free radicals. But a more complicated EPR spectrum results when the magnetic fields of the atoms in the radical interact with those of the unpaired electrons. Successful interpretation of such a spectrum makes it possible to describe the architecture surrounding the unpaired electron in considerable detail.

EPR has been able to verify a hypothesis long held by scientists concerning the structure of the so-called ionic crystals; it was held that certain types of irregularities of "defects" in these crystals consist of electrons trapped in sites left vacant by ions. But since the electrons are free to some extent, they should, and do, give rise to EPR. Similar unpaired electrons have been discovered through use of EPR in irradiated solid plastic polymers, caramelized glucose, tars, and certain charcoals and natural coals.

EPR has also been able to provide more information on the role of free radicals as intermediates in biochemical processes. Unpaired electrons have been detected in some oxidation-reduction reactions produced by certain enzymes, and it has been found that free radicals are formed as the result of the increased metabolic activity induced by the germination of seeds or the illumination of green leaves. Since the EPR technique is so sensitive, it has also been suggested for detecting any unpaired electrons that may take part in carcinogenic processes, where free radicals have been viewed suspiciously for some time. END

Vibration Pickups

Three new vibration pickups are said to be particularly suited for in-flight monitoring of jet engines and other constantly vibrating equipment such as motors and generators. Operable over the temperature range of −65 degrees F to +500 degrees F, these small pickups, known as Types 4-121, 4-122, and 4-123, will perform with precision in oily or corrosive atmospheres. Sand, dust, or fungus cannot penetrate their hermetically sealed interiors. The 4-121 and 4-122 will monitor turboprop vibrations in the range of 15 to 2000 cps. The 4-123, with its 45 to 2000-cps operating range, is ideal for jet-engine monitoring where the lowest frequency encountered is about 50 cycles. Because of their light weigrt (only 4.25 ounces each, including connector), these pickups will not affect the vibration characteristics of the equipment under test. All three are air damped, and because of their unique internal construction, damping is practically unaffected by temperature changes within the operating range. Consolidated Electrodynamics Corp., Pasadena, Cal.

Circle No. 180 on Inquiry Card

WORTH FILING

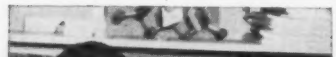
Magnetostrictive Delay Lines

The magnetostriction principle and its application to a wide choice of delay lines is covered in a handy loose-leaf manual in a plastic binder. Among delay-line types covered are laboratory-bench models, portable models, and component or built-in equipment; adjustable and fixed delay lines; and a memory unit especially intended for computer applications.

Source: Deltime, Inc.
Mamaroneck, New York

For your copy: Circle No. 109 on Inquiry Card

RESEARCH



STAFF COLUMNIST

Ronald C. Vickery

Ronald C. Vickery is Head of Horizons Incorporated's Chemistry Department.

THE CHEMISTRY OF COMPONENTS

Free Radicals: Energy Source For Space Travel

It might well appear that in my previous columns I have emphasized unduly the chemistry and applications of some of the more "exotic" elements and their unusual properties. I should say, however, that this was intentional. We still have much to learn about the commoner atoms and molecules, but we are in many instances aware of their general properties and how they can be modified or adapted to unusual requirements; but this modification, or adaptation, may not in itself be necessary—the properties and characteristics we desire may well lie simply available in the lesser known elements and their compounds, so that examination of these not only exposes their intrinsic properties but also may well demonstrate the possession of highly desirable uniqueness.

One can, of course, extrapolate this argument to idiotic limits, and we must be careful to avoid this. In some instances, however, it is difficult to avoid that great enthusiasm on which over-extrapolation is based, and one must be as objective and conservative as possible even when observed and calculated data present applications of wide-reaching importance. Such is the case when we consider the topic presented by Szego and Mickle on "Free Radicals as High-Energy Propellants," presented at the twelfth annual meeting of the American Rocket Society. I feel no qualms about introducing such a topic in a design journal, since the design of any equipment must be controlled by its components and the media it has to deal with. We all hope and expect that space travel by rocketry will become commonplace in our time and, if we compare these hopes with those we entertained of the Wright brothers' "bird" and with the present-day importance of aircraft, then it is evident that we must be prepared to consider each and every possibility which the future may hold.

That conventional oxidation-type chemical fields impose serious limitations on rocket-propulsion systems is clear, even though the Sputniks were pushed into their orbits by such means. At the recent ACS meeting in New York, A. V. Grosse and J. F. Gall separately pointed out the energetic oxidizing action of fluorine, the energy content and temperatures of fluorine flames, and the high potential value of fluorine-derived chemicals for rocket propulsion. But even if we disregard the toxicity and corrosivity of this halogen, we remain limited to the maximum energy available therefrom for a given weight and volume. The energy limit for such purely chemical systems has been calculated by Tormey to be about 400 seconds specific impulse, and this limitation is one which must be surmounted if man is to reach out and touch the stars.

Many energy sources have been proposed for space travel, from Cyrano de Bergerac's bootstraps to solar and atomic energy, but in this column I want to consider more closely the implications of free radicals for such application.

WHAT ARE FREE RADICALS?

"Free" radicals is not a new term; Gomberg first recognized the entity of these species in 1900, and we now describe them as "unstable, molecular fragments of stable species," or, more specifically, as "species with no charge but with unpaired electrons in the outer electron shell." We recognize the progenitors of such species in aqueous solutions as ions; but these ions are charged—if the charge is removed, then we have what we may consider as "free" radicals. They have several typical reactions: they are all paramagnetic to some degree; in the gaseous state many of them will remove thin films of metals from hot glass and, in solution, can often induce polymerization of compounds having carbon-to-carbon double bonds. The hydroxyl free radical is also an intermediate in the suggested mechanism for the decomposition of the superoxide ion by water. Free radicals are generated wherever molecules are broken up by some energetic process: a chemical reaction, heat, an electrical discharge, the attack of ultraviolet light and cosmic rays on molecules in our upper atmosphere.

On following the history of research into free radical chemistry, one is astonished at their ease of production and yet their relatively recent discovery. Many technological advances, such as the use of tetraethyl lead as a fuel additive, which are now commonplace, depend upon free radical mechanisms. A relatively small number of free radicals (as few as one per thousand molecules) can keep a chain reaction running and, because each step takes only a fraction of a second, they turn out products at a great rate.

Not all free radicals are short-lived, however; there are species which have lifetimes of many days under suitable conditions, e.g., when they cannot react with air. The known long-lived types are mainly hydrocarbons, usually consisting of thirty or more atoms, which can be preserved by dissolving them in benzene or similar inert solvents. But it is short-lived radicals, where lifetimes are usually measured in thousandths of a second, which are the most abundant and the most interesting. They are generally simple in structure and consist of only a few atoms: hydroxyl and methyl radicals are typical.

APPLICATION POTENTIALS

The use of free radicals also provides a powerful new tool with which to probe the structure of solids. The spectra of the light emitted by the free radicals trapped in a solid can give information about the arrangement of the atoms and molecules in the solid, about the forces acting upon them, about the movements of atoms, and about reactions between atoms and molecules.

But immediate importance lies not in the history nor the academic interest of these species but in their application. Even the simplest radicals—those of hydrogen, oxygen, fluorine, methyl, nitrogen, and neon—contain many hundreds of times as much energy as their parent species, and, since the performance of a rocket fuel is dependent upon the energy content of the propellant, it is clear that the hydrogen free radical, having a dissociation energy of about 51 K cal/gm, will give a specific impulse of the order of $1 \times 10^{3.5}$ seconds, while that of helium will be approximately $1 \times 10^{3.7}$ seconds. (Compare these with the 400 seconds I_{sp} limit of conventional chemical fuel, I_{sp} (seconds) = $208 \sqrt{H_c}$ (K cal/gm). Rather tangentially these impulse values present an interesting conception of the energetics involved in electron jumps between orbital levels.

If helium or neon is suitably energized, an outer orbit electron will transfer to a higher energy level and, on return to its ground state, would liberate the same energy. Selection rules preclude this direct return, however, and the atom is thus in a highly energetic and metastable state.

As I have indicated above, free radical formation is relatively easily accomplished; Paneth and Rice and their coworkers have shown that pyrolysis, or thermal dissociation, will give free radicals from almost all organic compounds, although it does not follow that *all* high-temperature vapor-phase reactions are free-radical in character. Photolysis also effects free radical formation, although to a lesser extent than pyrolysis. It also seems likely that a large number of electrolysis reactions involve the formation of free radicals, while irradiation with thermal neutrons is another mode of formation.

CONCENTRATION AND STABILIZATION PROBLEMS

The high reactivity of free radicals precludes—or rather has hitherto precluded—their collection in appreciable concentration, but, in the case of atoms and some very simple radicals, the high energy involved in this reactivity proves the reaction's undoing. The energy remains in the molecule and is usually not lost readily as a quantum of light. In a complex molecule the energy is distributed over the whole molecule, adding to the energy of a number of internal vibrations and rotations. It is highly improbable that all of the energy will be concentrated in one bond so as to cause its rupture before the molecule is energetically equilibrated with the rest of the system by collisions with other molecules and the walls of the container. In a diatomic molecule, however, the energy must be transferred by collision *very* quickly after the molecule is formed or it will dissociate again. Because of this, many pairing reactions occur only at walls or in the gas phase at termolecular collisions.

Szego and Mickle have summarized as follows the problems in applying free radical energetics to propulsion:

- By what means may these energetic species be generated?
- To what levels may they be concentrated?
- How and for how long may they be preserved without reaction?
- How may their recombination or return to their ground state be initiated and controlled?

Modes of free radical formation are now well established, but the problems of concentration and stabilization now require attack, and are so being attacked.

Hitherto the most effective technique for concentration and stabilization has involved low temperatures. Although the larger, less energetic radicals can be maintained as such in inert solvents, the simpler, highly reactive radicals survive in their isolated state for only hours at temperatures near 4°K.

Reasons for such a degree of stabilization are as yet unclear. Most probably the free radicals are separated, in the condensed surfaces, by unreactive molecules and atoms in a rigid framework. As temperature increases, the framework relaxes somewhat and allows the radicals to move sufficiently to combine with each other. Thus, two nitrogen atoms may meet and form the stable nitrogen molecule. In this process they give off just as much energy as is required to tear apart the two atoms of a nitrogen molecule. About half of the energy released on combination is radiated as light by the newly formed molecule, and the rest is in the form of heat. The color of the light emitted is a measure of the energy to break up a given molecule.

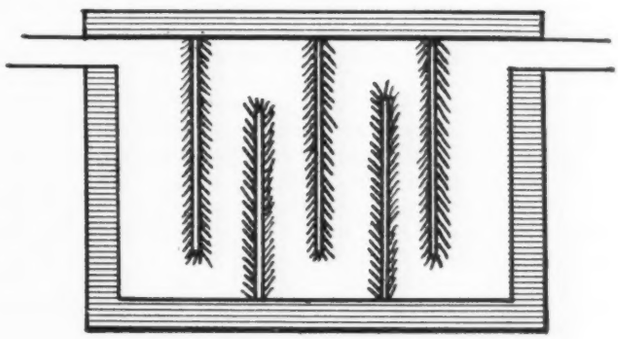
Use of low temperatures for freezing out the free radicals has been applied almost since the beginning of serious study of these systems. By solidification in appropriate circumstances, rate of collision can be slowed to the point of near-stabilization. This technique is in general use but has its limitations in applications to rocket propulsion by virtue of the equipment required for refrigeration of free radical systems.

A NEW APPROACH

An alternate technique of stabilization lies, of course, in adsorption of free radicals on the walls of a container. In essence, this adsorption plays a part even in cryoscopic stabilization, but hitherto there does not appear to have been examined the possibility that less low temperatures might be required if the adsorbing medium be other than, e.g., glass. We know, for example, that some free radicals can be retained in benzene, etc., but how strongly would the more energetic free radicals be adsorbed and stabilized in monomolecular films of highly polymerized and strongly cross-linked materials? This consideration might appear to be offset by the possibility of degradation of the polymeric film, but there are extant no observations on such systems. A degree of cooling may, and probably would, be necessary, but the closer one approaches normal temperatures the less the equipment weight necessary for refrigeration.

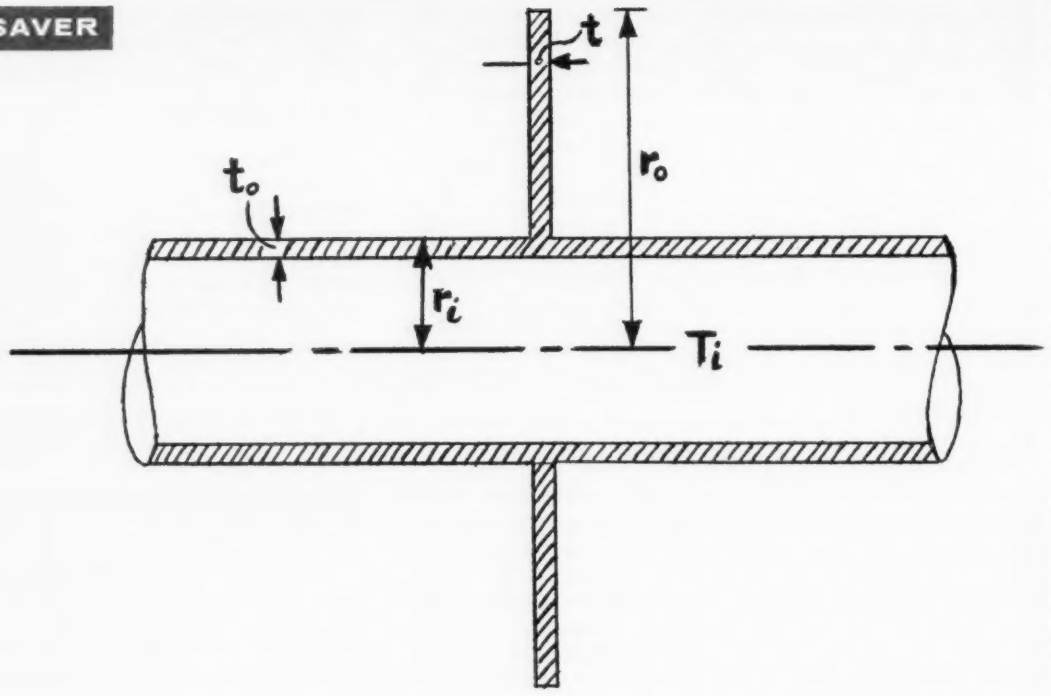
Together with stabilization of free radicals we must, however, consider their concentration. The mutual reactivity of free radicals controls to a large extent the maximum concentration which they can establish, since, with increasing concentrations, the radicals approach each other more closely and the chances of their kinetic paths crossing are increased. Thus, for any degree of stabilization there is attained a comparable degree of concentration.

It is clear, therefore, that maximum stability and concentration can be obtained only when the free mean path of the free radical is completely restricted. Cooling and adsorption are two factors whose application we have briefly discussed. But there is a third factor which can be applied. Because free radicals almost invariably contain an odd number of electrons, they are somewhat paramagnetic. Can this feeble paramagnetism be applied to the problems of stabilization and concentration? By itself, I think not. But, in combination with the other factors of cooling and absorption, there might exist a good possibility of attaining the desired degree of effectiveness.



Consider, for example, a system such as that shown in the sketch. Each baffle in the refrigerating chamber is a thin, permanently magnetic sheet, coated with a monomolecular film of a highly crosslinked high polymer such as polystyrene. Cooling will partially restrict activity of the radicals, and these would be further stabilized by adsorption into the polymer. Through the polymer film magnetic attraction will further restrain activity. Radical release would be simply effected by cessation of refrigeration and, as far as I know, such a tripartite system has not been investigated, but there would seem no fundamental obstacle to the erection and function of such a system. Undoubtedly several variants of magnetic and polymer materials would have to be examined and many parameters established, but the procedure would present a very interesting experiment. END

DESIGN TIME SAVER



H. D. Conway

STRESS ANALYSIS OF AN ANNULAR FIN-PIPE ASSEMBLY

A common method for increasing the heat emitted from a circular pipe is by means of circular fins concentric with the pipe and frequently made integral with it. Temperature distribution and heat dissipated by such a fin form the subject of a paper by W. M. Murray in the Journal of Applied Mechanics, Vol. 5, No. 2, 1938, titled *Heat Dissipation Through an Annular Disk or Fin of Uniform Thickness.* In this paper Murray gives sample numerical calculations. He assumes the spacing is sufficiently large for the fin to be treated independently of its neighbors and states that where this assumption is valid, good agreement exists between theory and experiment.

The present investigation might be considered a partner to the foregoing work, in that it assumes the temperature distribution given therein and attempts to estimate the magnitudes of the thermal stresses induced in the fin-pipe assembly. It thus assumes the fin spacing inherent in Murray's calculations and it also assumes that this spacing is sufficiently large for the pipe deformations to die out between fins.

ANALYSIS

Figure 1 shows a diagram of the problem to be solved, the thicknesses of fin and pipe being small compared with other dimensions. Assume that the assembly is free from stress at air temperature, and consider that the pipe is then called upon to transport fluid at a uniform temperature T_i above the air temperature. The problem is —what stresses are induced by this change?

Consider first the fin in which the axisymmetrical temperature distribution can be assumed constant throughout the thickness t, since the latter is small. If the coefficient of thermal conductivity of the material is denoted k, and the surface emissivity h of the surface of the fin is constant, it may be shown according to Murray that the temperature rise in the fin at radious r is given by

$$T = AI_o(\gamma r) + BK_o(\gamma r)$$
$$\gamma^2 = 2h/kt \qquad (1)$$

I_o and K_o are modified Bessel functions of zero order, and A and B are constants found from the temperature boundary conditions.

The first equation follows from the fact that the rate of heat brought to the outer fin radius is equal to the rate of heat transmitted to the atmosphere, whereas the second requires a knowledge of the temperature at the inner radius. The second is unknown but, since the wall of the pipe is thin, it is thought that the temperature rise at the inner radius may be taken as T_i, the temperature above that of air of the fluid transmitted by the pipe. The boundary conditions are then expressed as

$$r = r_o, \; -k(dT/dr) = hT$$
$$r = r_i \;\; T = T_i \qquad (2)$$

and, from Equation (1), the constants A and B are respectively

$$A = \frac{T_i[k\gamma K_1(\gamma r_o) - hK_o(\gamma r_o)]}{d}$$
$$B = \frac{T_i[hI_o(\gamma r_o) + k\gamma I_1(\gamma r_o)]}{d} \qquad (3)$$

where:

$$d = k\gamma[I_o(\gamma r_i)K_1(\gamma r_o) + I_1(\gamma r_o)K_o(\gamma r_i)]$$
$$- h[I_o(\gamma r_i)K_1(\gamma r_o) - I_o(\gamma r_o)K_o(\gamma r_i)]$$

To overcome heat problems in electromechanical systems, more and more engineers are resorting to the use of finned designs. Here's a Design Time-Saver *that shows you how to calculate thermal stresses in annular fins to avoid failures that could result from these stresses. Sample problem—worked out in detail—starts on page 57. This article is based on work performed at General Electric's Advanced Electronic Center in Ithaca, New York.*

Harry Donald Conway
Contributing Editor

H. D. Conway has a Ph.D. and D.Sc. from London University. He has worked as a stress analyst, a scientific officer at the National Physical Laboratory in England and is now Professor of Mechanics and Materials at Cornell University. He has published over 70 papers in theory of elasticity, stress and vibration analysis. In 1953-1954 he was a Visiting Professor, Imperial College of Science, London University, on a John S. Guggenheim Foundation fellowship. His textbooks include *Aircraft Strength of Materials* (Chapman & Hall, London, 1947) and *Mechanics of Materials* (Prentice-Hall, New York, 1950).

We next consider the stresses. For an axially symmetrical system such as the present one, it is known—from *Theory of Elasticity*, by S. Timoshenko and J. N. Goodier, McGraw-Hill Book Co., Inc., New York, 1951, p. 406—that the radial and circumferential stresses and radial displacement in the fin are given respectively by

$$\sigma_r = \frac{-\alpha E}{r^2}\int_{r_i}^{r} \mathrm{Trdr} + \frac{E}{1-v^2}\left[C_1(1+v) - \frac{C_2}{r^2}(1-v)\right]$$

$$\sigma_\theta = \frac{\alpha E}{r^2}\int_{r_i}^{r} \mathrm{Trdr} + \frac{E}{1-v^2}\left[C_1(1+v) + \frac{C_2}{r^2}(1-v)\right]$$

$$u = \frac{\alpha(1+v)}{r}\int_{r_i}^{r} \mathrm{Trdr} + C_1 r + \frac{C_2}{r} \qquad (4)$$

where:

α is the linear coefficient of expansion of the material, C_1 and C_2 are constants found from the boundary conditions, T is given by Equation (1). Thus,

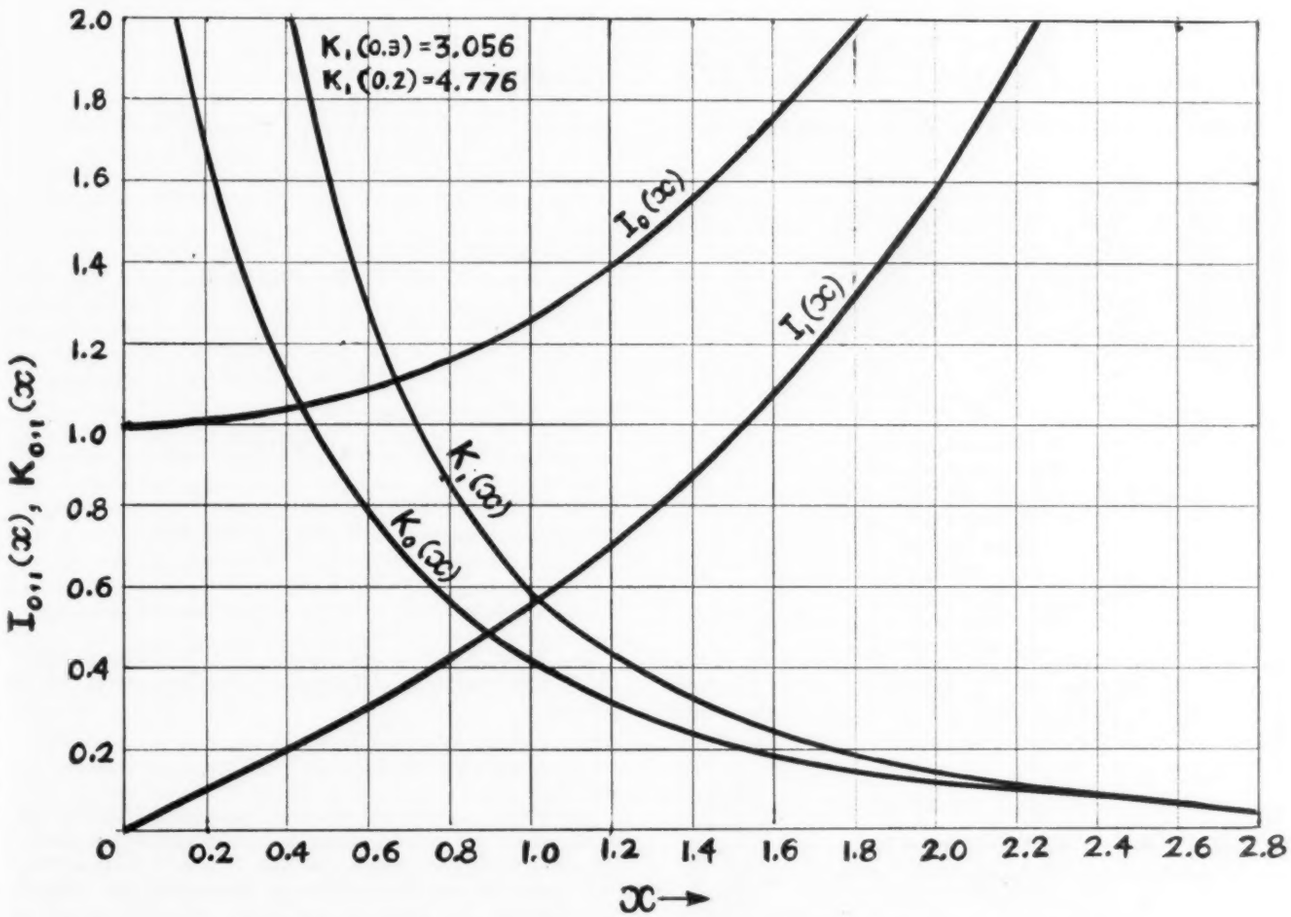


Fig 2 Values of modified Bessel functions may be read directly from this graph.

$$\sigma_r = -\frac{\alpha E}{\gamma}\left[\frac{A}{r} I_1(\gamma r) - \frac{B}{r} K_1(\gamma r)\right]_{r_i}^{r} + \frac{E}{1-v^2}$$

$$\left[C_1(1+v) - \frac{C_2}{r^2}(1-v)\right]$$

$$\sigma_\theta = \frac{\alpha E}{\gamma}\left[\frac{A}{r} I_1(\gamma r) - \frac{B}{r} K_1(\gamma r)\right]_{r_i}^{r} + \frac{E}{1-v^2}$$

$$\left[C_1(1+v) + \frac{C_2}{r^2}(1-v)\right]$$

$$u = \frac{\alpha(1+v)}{\gamma}\left[A_1 I_1(\gamma r) - B K_1(\gamma r)\right]_{r_i}^{r} + C_1 r + \frac{C_2}{r} \qquad (5)$$

Now, at $r = r_i$, the Bessel function terms in the above equation are zero, and hence the force P per unit circumferential length at the junction of fin and pipe is

$$P = t\sigma_{r\,r=r_i} = \frac{Et}{1-v^2}\left[C_1(1+v) - \frac{C_2(1-v)}{r_i^2}\right] \qquad (6)$$

Also

$$u_{r=r_i} = C_1 r_i + \frac{C_2}{r_i} \qquad (7)$$

It is now necessary to compute C_1 and C_2. At $r = r_o$, the radial stress is zero and hence, from the first of Equation (5)

$$\frac{-\alpha E}{\gamma}\left[\frac{A}{r} I_1(\gamma r) - \frac{B}{r} K_1(\gamma r)\right]_{r_i}^{r_o} + \frac{E}{1-v^2}$$

$$\left[C_1(1+v) - \frac{C_2(1-v)}{r_o^2}\right] = 0 \qquad (8)$$

The second equation is obtained by equating the radial displacements of the fin and pipe at their common junction. Assuming that the fin is sufficiently far from its neighbors and from the end of the pipe, it is known from elementary cylindrical-shell theory that the radial displacement of the pipe due to the force P per unit circumferential length is

$$P/8\beta^3 D$$

where

$$\beta^4 = \frac{Et_o}{4r_i^2 D} = \frac{3(1-v^2)}{r_i^2 t_o^2} \text{ and}$$

$$D = \frac{Et_o^3}{12(1-v^2)}$$

is the flexural rigidity of the pipe. The increase in the radius r_i of the pipe due to the temperature rise T_i is $\alpha r_i T_i$ and the equation obtained by equating the radial displacement of pipe and fin at their common junction is then

$$C_1 r_i + \frac{C_2}{r_i} = \frac{P}{8\beta^3 D} + \alpha r_i T_i$$

$$= \frac{3t}{2\beta^3 t^3}\left[C_1(1+v) - \frac{C_2(1-v)}{r_i^2}\right] + \alpha r_i T_i \qquad (9)$$

To sum up, the temperature distribution is given by Equation (1) with Equations (3). The constants C_1 and C_2 are then found from the simultaneous Equations (8) and (9), and the stresses and displacement from Equations (4). Since tables of the modified Bessel functions are frequently not available, graphs of these functions are given in Fig. 2.

For the pipe, the radial force P per unit length [Equation (6)] induces a moment $P/4\beta$ and thus the maximum longitudinal bending stress at the junction is

$$P/4\beta \cdot 6/t_o^2 = 3P/2\beta t_o^2 \qquad (10)$$

EXAMPLE

A numerical example will now be worked out using the data from an example in the paper by Murray on the heat transfer of annular disc fins. These data are:

$r_o = 1.75$ inches
$r_i = 0.75$ inch
$h = 2.1$ Btu per square foot per degree per hour
$k = 26$ Btu per square foot per foot per degree per hour
$\alpha = 6.5 \times 10^{-6}$ per degree F
$t = t_o = 1/8$ inch
$\nu = 0.3$
$E = 30 \times 10^6$ psi.

From the above:

$$\gamma = \sqrt{\frac{2 \times 2.1}{26 \times 0.125 \times 12}} = 0.328 \text{ inches}^{-1}$$

$\gamma r_o = 0.328 \times 1.75 = 0.574$
$\gamma r_i = 0.328 \times 0.75 = 0.248$
$\beta 4 = (3 \times 0.91 \times 64)/(0.75)^2 = 311$ inches^{-4}
$\beta 3 = 73.985$ inches^{-3}

From Fig. 2:

$I_o(\gamma r_o) = 1.084$; $I_o(\gamma r_i) = 1.015$
$I_1(\gamma r_o) = 0.299$; $I_1(\gamma r_i) = 0.124$
$K_o(\gamma r_o) = 0.816$; $K_o(\gamma r_i) = 1.578$
$K_1(\gamma r_o) = 1.395$; $K_1(\gamma r_i) = 3.985$

From Equation (3):

$A = 0.7371\ T_i$; $B = 0.1718\ T_i$

and, from Equations (8) and (9):

$2.3780 \alpha T_i = 1.483 C_1 - 0.2512\ C_2$
$0.75 \alpha T_i = -0.937\ C_1 + 2.948\ C_2$

Solving the latter gives

$C_1 = 1.74 \alpha T_i$, $C_2 = 0.81 \alpha T_i$

Thus, from Equations (4):

$\sigma_{r\ r=r_i} = 1.382\ E\alpha T_i = 270\ T_i$
$\sigma_{\theta r=r_i} = 3.591\ E\alpha T_i = 700\ T_i$

The latter is the largest stress in the fin. From Equation (10), the maximum longitudinal bending stress in the pipe is

$$\frac{3 \times 270 \times 0.125\ T_i}{2 \times 4.2 \times (0.125)^2} = 770\ T_i$$

The above stresses are estimated assuming that the pipe is subjected to loading along a line whereas the load is actually distributed over a width of 1/8 inch. This assumption probably has the effect of increasing the stresses. Nevertheless, the stresses are large even for small increases in temperature.

MANAGEMENT

EUROPEAN COMMON MARKET

Wanted for Export: U. S. Products, Processes and Know-How

If you have not considered leasing or licensing your new product or process for sale and application in Eupope, now may be the time to do so. Normally, U.S. companies desiring to expand overseas have several procedures available to them. Perhaps the most expensive and difficult is the creation of a subsidiary manufacturing operation complete with research, development and sales organizations. Such expansion requires large capitalization and the expenditure of a great deal of effort and energy in finding the appropriate people, technical, legal and sales, and creating acceptance within the particular country. Even the simple procedure of sending an executive to Europe to arrange for licensing or outright sales agreements can be a costly and time consuming operation.

Because of common tariff and regulation laws the creation of the European Common Market, consisting of six countries—France, West Germany, Italy, Belgium, Netherlands and Luxembourg—will undoubtedly decrease some of the problems hitherto confronting U.S. companies desiring to get established in Europe.

These facts were presented to us by Mr. Albert L. Roncey of La Compagnie Financière, 45 Rue de Faubourg Saint-Honoré, Paris 8, France, who dropped into our office to give us some details of the European Common Market on his way to a series of meetings with companies throughout the United States. Mr. Roncey, with six years of experience in representing American companies in Europe, has joined La Compagnie Financière as head of their licensing department.

Mr. Roncey pointed out that international exchange of patents, processes, machines, ideas, problems, equipment and know-how are pretty well known procedures within the legal and financial departments of U.S. companies. Many are forced into creating subsidiaries overseas since foreign governments are reluctant to permit the payment of dollars for machinery and equipment and only do so after reams of red-tape have proven that the equipment is truly essential to the country. However, these same governments are less reluctant in permitting the payment of royalties in dollars. Normally, royalty payments are the means by which new processes and products only available in the United States become available to the European country. Moreover, licensing can create work and in many cases utilize materials and supplies obtainable within the country. Thus the total payments of royalties to a U.S. company is a smaller sum since it represents some portion of the profit and not material, labor, transportation and other primary costs. By the same procedure these governments hope to create a national industry that will expand, develop and be a source of taxes as well as employment.

Mr. Roncey pointed out that normally these countries only permit the payment of these royalties on products and processes not competitive with current industry and payment of dollars will only accrue to those products and processes not normally available to them.

Through Mr. Roncey, La Compagnie Financière is set up to offer American companies two services that they feel are unique when considered together.

continued on p. 60

"MONOBALL"® Self-Aligning Bearings

CHARACTERISTICS

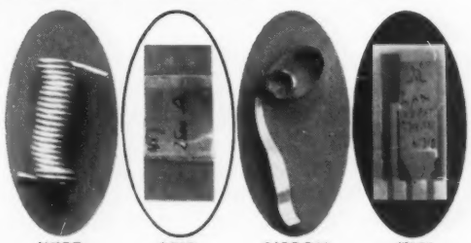
	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Moly Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Moly Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for revised Engineering Manual describing complete line to Dept. EMD-58.

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE 23 ON INQUIRY CARD

NOW DUCTILE BISMUTH in wires, grids, ribbons and films!



WIRE GRID RIBBON FILM

At last you can take advantage of Bismuth's extreme sensitivity to changes of temperature and magnetic field intensity. Through an exclusive process, we have perfected Bismuth in ductile form . . . Bismuth that can be bent without crumbling and breaking. Available in insulated or bare wires, in special alloys for thermocouple legs, in wire form or grids for resistance controlled circuits and gauss meters, and in ribbons or plastic mounted films for Hall effects. No other material is so versatile in its application to control and testing instrument design.

BISMUTH THAT BENDS HAS 1001 USES IN TESTING AND CONTROL INSTRUMENTS!

Write for Complete Information And Prices:

Fitzpatrick ELECTRIC SUPPLY CO.
446 IRWIN ST. • MUSKEGON, MICHIGAN

CIRCLE 24 ON INQUIRY CARD

continued from p. 59

- They undertake to locate within the European Common Market the best possible arrangement for a licensee, negotiate the license in the name of the American licensor and then submit the agreements for the approval of the American company—all at the expense of La Compagnie Financière. La Compagnie Financière also undertakes to follow up and maintain the working arrangements, see that royalties are paid on time, re-negotiate the contract whenever necessary and in general maintain all necessary business relationships between the licensor and the licensee.

Perhaps the most unique aspect is the fact that La Compagnie Financière is prepared to undertake these two steps at their own expense should negotiations fail to materialize and also is prepared to wait for their own participation in royalties until fees are paid to the American company. Mr. Roncey pointed out that his company is interested only in products and processes already proven out on the U.S. market and particularly in those products and processes and know-how that are not normally available for sale in Europe. According to Mr. Roncey, his firm is the largest company of its type to enter into this type of systematic representation on a large scale basis.

WORTH FILING

Airborne Data Link

Ten-page booklet provides technical information about LABIL (Light Aircraft Binary Information Link). The system enables an aircraft pilot to transmit automatically 13 separate categories of flight information to a ground control tower simply by flipping a switch. The plane's standard voice transmission equipment is used for the transmission. The pilot adjusts selector knobs to record such data as identification, departure point, destination, estimated time of arrival, present position, altitude, airspeed, time of report, flight time remaining, and other data. When a visual signal indicates a tower request, the pilot depresses a single key, automatically transmitting the entire stored message to the control center. There the information is fed into a teletypewriter which prints it out in a single line, making it easily correlated with information received from any number of other aircraft. The airborne LABIL data link is completely transistorized, and is assembled in a cabinet only 13 inches high, 10 inches wide, 6 inches deep, and weighing 25 pounds.

Source: Stromberg-Carlson Division
General Dynamics Corp.
Rochester, New York

For more information: Circle No. 186 on Card

STAFF COLUMNIST

Renato Contini
Research Coordinator of
New York University, New York, N.Y.

HUMAN FACTORS IN DESIGN

Human Engineering is the second major discipline to emerge in this area of human factors. The term itself is controversial and has been criticized by many in the engineering profession. I feel, therefore, that human engineering could best be described by one who has been trained in experimental psychology, and who has practiced in the field. Mr. Joseph Ruocco, a member of the research staff of the College of Engineering at New York University, has conducted a research program for the military for a number of years. Here is the trend as he sees it in his own words.

World War II created the need for increased emphasis in the area of human factors as it pertains to engineering problems. Unfortunately, in the minds of many engineers, this infant science, sired by a World War and nurtured by government funds, has been relegated exclusively to an existence of military service. The full potential and usefulness of this specialty will not be realized until this notion is dispelled.

The application of known psychological principles to equipment design, control systems and to other areas of equipment usage and operation are by no means necessarily limited to military hardwares. Basically, human engineering aims at optimizing that entity commonly known as the "man-machine system". The "system" can be as specialized and complex as a vast air defense network; it can also be as commonplace and simple as the housewife using her stove.

Human engineering data can often be of the simplest sort and the suggested changes miniscule. Yet in an economy of mass production and split second timing, results can pay off handsomely. An almost classic illustration of a human engineering improvement is in the latest design of the telephone. Previously, numerals and letters were printed on the inside of the dial. It was expected that, moving them outside the dial would decrease errors and dialing time; cutting down errors and dialing time means that the same amount of equipment can handle a greater number of message units—a substantial saving when considered in terms of millions of calls. The improvement was carried one step further; a little white dot was placed in the center of the now empty dial hole, decreasing dialing time approximately one-tenth of a second—in terms of dollars, a substantial saving!

Gradually, much of the basic, relatively static and generally applicable data of human engineering (such as visibility curves, display principles, body metrics, reaction times, etc.) are being collected in handbook form and attempts are being made to put these data—gathered as a result of the research efforts of many diverse disciplines—into language readily understandable to and useful for the engineer. As recognition for the need of human engineering grows I expect that a change in the character of this specialty will be shown in at least three ways. First, human engineering will be accepted as the adjunct it is to engineering science and will no longer be regarded as an intrusion upon the prerogatives of the project engineer, nor be limited in the main to military application. Second, a formal course of training will evolve and the human factors specialty will no longer be a polyglot conglomeration of individuals trained in many disparate disciplines. Finally, I think their contributions will be concerned more with the complex and the integral aspects of system operation and less with the "obvious" and superficial side of equipment performance. Information flow, procedural parameters, maintenance speed and ease are as much a part of any system as the circuitry and the knobs and dials, and these will be given the increasd consideration they deserve. A system's "figure-of-merit" will no longer be summarized in a few voltage readings but will come to include the variances introduced by that most unpredictable of all elements—man.

WORTH FILING

Electromechanical Breadboard Parts

Twenty-four page catalog of standard electromechanical breadboard parts lists 117 parts cross-indexed for easy reference. Charts and descriptions maintain a mail order catalog-type simplicity. All dimensional drawings are reproduced in in two colors for greater readability.

The catalog lists basic components such as grid plates, shaft hangers, component hangers, shaft couplings, shaft hardware, shafting, electric and mechanical limit stops, magnetic clutches and ball and disc integrators.

Source: Beckman/Helipot Corp.
Newport Beach, Calif.
For your copy: Circle No. 196 on Inquiry Card

WORTH FILING

Pyrocerams in Production

Eight page progress report by Corning Glass Works announces production of Pyroceram types 9606 and 9608 and discusses their properties and applications.

Pyroceram is an opaque ceramic that starts out as a glass. Nucleating agents in the glass form centers of crystal growth on subsequent heat treatments, turning the material into a hard, white ceramic. A thin-walled tube of Pyroceram 9608, developed for use in high temperature heat exchangers, can be heated to 1300°F and then plunged into ice water with no effect.

Current production schedules on a continuous melting tank call for Pyroceram tubing with various diameters and lengths up to ten feet, Pyroceram rod and sheet, as well as pilot runs of blown and pressed ware.

Pyroceram 9608 is described by the company as a general purpose material. With a mechanical strength equal to that of cast iron, it also combines great hardness with an extremely low coefficient of thermal expansion up to 1800°F. Production experience with this material indicates that it can be formed by any high-speed glass manufacturing method.

Its hardness, combined with its ability to operate at high temperatures without deforming or softening, gives Pyroceram 9608 excellent characteristics for bearing parts. Other commercial applications of these new materials now being investigated include tubing for high-temperature heat exchangers, low expansion piston heads, precision-made aircraft structural parts and architectural curtain walls.

Source: Corning Glass Works
Corning, New York
For your copy: Circle No. 195 on Inquiry Card

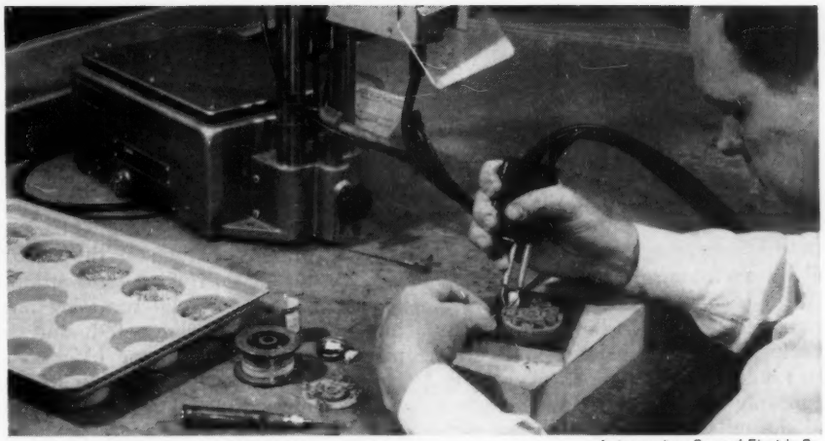


photo courtesy General Electric Co.

WELDMATIC PRECISION WELDER BOOSTS RELIABILITY IN SUBMINIATURE COILS

You, too, can make reliable joints in millisecond time with a Weldmatic. Here, at the Advanced Engineering Laboratory of the General Electric Light Military Electronic Equipment Department, welding of a 0.005" terminal to #38 copper wire in subminiature toroids is being done with a Weldmatic 1015. Weldmatic joints withstand high temperature, severe vibration and acceleration. Unit sets up fast, is simple to operate. Write for technical data on the Weldmatic line.

WELDMATIC DIVISION OF UNITEK CORPORATION
276 North Halstead Avenue • Pasadena, California

SALES ENGINEERING REPRESENTATIVES IN PRINCIPAL CITIES

FOR MORE INFORMATION CIRCLE 25 ON INQUIRY CARD

MATCHING AMPLIFIER

Elasco's Model K Matching Amplifier is a stabilized amplifier with a very low internal output impedance, approximately 1—j0.2 ohms at 60 cps. It is designed to permit the use of accurate low-sensitivity voltmeters and wattmeters on relatively high impedance circuits. The Model K Matching Amplifier will develop full output of 150 volts rms across a 2000 ohm load at frequencies from 20 cps to 2000 cps.

INPUT IMPEDANCE:
Resistive: E/R $\leq$ 150 Microamps

OUTPUT IMPEDANCE:
1.0 ohm in Series with 15,000 Mfd

INPUT VOLTAGE, MIN.:
1.5 volts rms

INPUT VOLTAGE, Max.:
600 volts rms

OUTPUT VOLTAGE, MAX.:
150 volts rms

FREQUENCY RESPONSE:
0.15%—20-2000 cps
2.0%—3-15,000 cps

SEND FOR CATALOGUE

ELECTRONIC ASSEMBLY COMPANY, INC.

Five Prescott Street • Roxbury 19, Mass.

FOR MORE INFORMATION CIRCLE 26 ON INQUIRY CARD

LETTERS

continued from p. 2

computer treatment of a problem contains the elements of both a simulation approach and a mathematical approach, since an analog computer, according to long-standing usage, is *both* a model and an equation-solver.

With regard to the loading of potentiometers, I find it difficult in many practical cases to reconcile his two statements, one with regard to precalibrating coefficient potentiometers and the other indicating that one simply chooses the resistance ratio desired for a given maximum coefficient. It is a matter of common knowledge that most large general purpose computors, for the sake of economy, have their potentiometers in uncommitted utility banks, and a given potentiometer does not know in advance if its load is to be 1, 4, 10, or any other number of micromhos. For such a computor, precalibration of its ten-turn potentiometers to fit all possible cases would be extremely difficult.

With regard to inversion:—The inverter is never wasted in the Universal Linear Operator, because it is an essential part of the scheme whereby a saving of about 25% in the number of precision decade resistors is effected. (Mr. Lange, and many of your readers, may have found Figure 1b, a simplified schematic, somewhat misleading). Thus, what might at first glance appear to be a source of increased cost is actually an instrument of cost reduction; and inversion is obtained simply by reversing the symmetry of the decade arrangement.

It is also worthwhile to consider the benefits of having all the variables in a problem available in an inherently positive sense. Much of the confusion that occurs in tracing signs around loops with conventional summing amplifiers is thereby eliminated, and in many cases, the computor block diagram can be dispensed with entirely. In particular, direct setup from matrix equations becomes practical.

Mr. Lange seems to miss the point entirely when he envisions many requirements where both signs will be needed—let us consider some of the most commonly used routings of a given variable:

a) To several Universal Linear Operators: the sense of the input to each may be chosen independently.

b) To an arbitrary function component: because the function is arbitrary, input sense is usually unimportant, especially in the case of selection-type function fitters.

c) To a Multiplier: because a multiplier may be thought of as a variable coefficient, the sense of a given input operates directly on the product, whose subsequent treatment is governed by (a) or (b) above.

Incidentally, the existence of the Universal Linear Operator does not preclude its use in conjunction with other types of equipment, *including* conventional operational amplifiers.

After questioning the appropriateness of our built-in inverter and our objections to potentiometers, Mr. Lange finds that "two features . . . are noteworthy: the three-dial decades for all parameter settings, and the plus-off-minus" switches for the coefficients," the former prompted by the discomforting features of potentiometers, the latter using as its mainstay the built-in inverter. We might have added to the list of noteworthy features the choice of forms (integration, or direct addition) and ranges (in powers of ten) by simply setting a switch, and the introduction of a precise adjustable index voltage in each unit to act as initial conditions or an additive constant.

With regard to cost, although specific figures are definitely not appropriate in these columns, if Mr. Lange were to investigate, he might be quite pleasantly surprised. And, finally, as Mr. Lange so rightly points out, the user must always strike a balance, with the end in view being the economic choice of the most significant problems solved per dollar. We can only throw our hat (and our history) into the ring and say, "Ask the man who owns one."

Daniel H. Sheingold
Director of Applications Engineering
George A. Philbrick Researches, Inc.

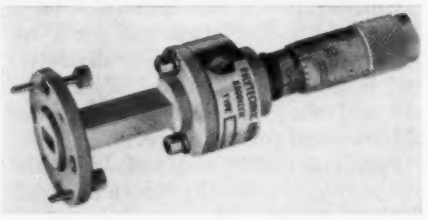
Ultrasonic Soldering Iron

An ultrasonic soldering iron has been designed for soldering without flux materials such as aluminum and magnesium and their alloys, and for other uses where it is necessary to avoid the corrosive effects of flux. In operation, ultrasonic vibrations break the oxide layer of metals and alloys that form refractory oxides and enables such metals to be effectively soldered without any special surface pretreatment. Additional applications include surface tinning and the filling of blowholes in aluminum and magnesium castings, the soldering of light metal pipes or gutters which are not easily accessible for bench work and the assembly and installation of wave guides. The patent application claims that the technique employed permits higher soldering tip temperatures because of the minimum loss in transmitting heat from the transducer to the soldering tip. The instrument can be used with electrically heated or gas heated soldering tips. Gulton Industries, Inc., Metuchen, New Jersey.

Circle No. 164 on Inquiry Card

Micrometer Driven "Sliding Shorts" for Waveguide Measurements

New "sliding shorts," which can be accurately adjusted to any reactance, are available in frequency ranges from 12.4 to 75 KMC/S. The manufacturer states that with short-circuit VSWR's of up to 100:1, the units are the most useful terminating impedances in waveguide measurements, with the exception of matched loads. The new units consist of a section of waveguide in which a short-circuiting plunger can be moved by means of a micrometer drive. They are non-contacting shorts of the two-section coaxial-filter type. The combination of non-contacting short circuit and micrometer drive is said to result in an unusually smooth motion that is both electrically and mechanically stable. Also, the use of a micrometer head makes it possible to note and repeat the relative position of each short for a particular tuning condition. In each case, the short circuit travel is greater than one-half wavelength at the lowest operating frequency, so that optimum tuning is possible over the entire frequency range. Sliding shorts are used with slotted sections to provide a variable short-circuit reference point. In conjunction with a tee section, they act as a variable reactance and can also provide tuning for crystal or bolometer mounts. Polytechnic Research & Development Co., Inc., Brooklyn, N.Y.

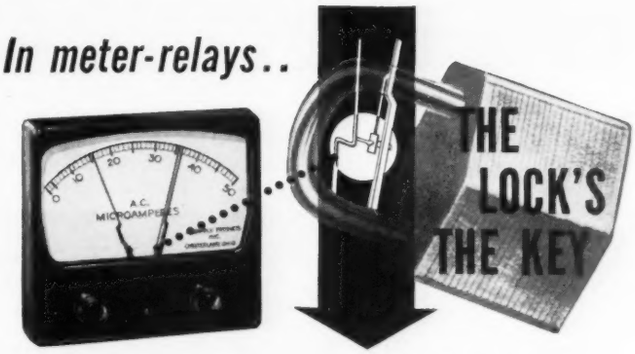


Circle No. 175 on Inquiry Card

ADVERTISERS' INDEX

ADVERTISERS	Page Number	Inquiry Number
A		
American Sealants Co.	2	2
Assembly Products, Inc.	63	27
AVCO Manufacturing	Cover 2	1
B		
Richard H. Bird & Co.	49	20
H. O. Boehme, Inc.	51	21
C		
Clifton Precision Products Co., Inc.	Cover 4	30
Continental Wire Corp.	11	4
D		
The Daven Co.	48	19
E		
Electronic Assembly Co., Inc.	52	22
Electronic Assembly Co., Inc.	61	26
Elgin National Watch *(Electronics Div.)*	23	11
F		
Fitzpatrick Electric Supply Co	59	24
G		
General Electric Co. *(Missile Guidance Product Section)*	Cover 3	29
Guardian Electric Mfg. Co.	21	8
G-V Controls, Inc.	23	9
I		
International Resistance Co. *(Hycor Div.)*	19	7
M		
Marion Electrical Instrument Co.	23	10
P		
George A. Philbrick Researches, Inc.	34	14
Joseph A. Pollak Corp.	7	3
Post Machinery Co.	13	5
S		
Saginaw Bearing Co.	17	6
Sealol Corp.	41	16
Slip Ring Co. of America	63	28
Southwest Products Co.	48	18
Southwest Products Co.	59	23
J. S. Staedtler, Inc.	37	15
U		
United Electric Controls Co.	45	17
Unitek Corp.	61	25
V		
Valcor Engineering Corp.	31	13
W		
Edwin L. Wiegand Co.	29	12

In meter-relays..



—to Contact RELIABILITY!

API locking coil meter-relays have wiping contacts which clean themselves with each operation. This self-cleaning assures maximum reliability, and is found in no other meter-relay.

When contacts touch, the locking coil grabs and holds them. They are sharply separated by a spring which is loaded during locking. This positive make and break gives 10 to 20 million trouble-free operations.

Ask for Catalog 4-D

Assembly Products Inc.

api

Chesterland 83, Ohio

Booth 1039, Design Engineering Show, April 14-17, International Amphitheatre, Chicago

CIRCLE 27 ON INQUIRY CARD

finest quality

SLIP RING ASSEMBLIES

made by EVERY known process...

UNITIZED ONE-PIECE CONSTRUCTION

100-Ring Missile Guidance Slip Ring Low Torque, Low Noise

Only Slip Ring Co. of America produces precision slip ring assemblies by every known process to meet your particular requirements — Transfer, Injection and Compression Molded, Cast, Fabricated, Vacuum Impregnated, Electro Deposited, Metal Sprayed, Printed Circuit, Mercury Pool. Sizes, .020" to 72" Dia. Circuits, 2 to 200 rings. Finishes, 2 micro inch RMS. Temperature, 650°F continuous. Vibration, 300 G's. Hi-pot, up to 15,000 volts. Longer life through wider material selection. Dielectrically superior insulating materials. Minimum noise with precious metals. Engineering consultation available.

WRITE FOR NEW BROCHURE

SLIP RINGS — BRUSH ASSEMBLIES — COMMUTATORS — SEALED ASSEMBLIES

Write for Literature

SLIP RING CO. OF AMERICA

CA

3612 West Jefferson Blvd.

Dept. ED Los Angeles 16, California

Representative sales engineers in major cities throughout the United States and Canada.

CIRCLE 28 ON INQUIRY CARD

MANAGEMENT

STAFF COLUMNIST

Herbert F. Spirer

Assistant Chief Engineer
CGS Laboratories, Inc.
Stamford, Conn.

SIX SIMPLE STEPS TO UNRELIABILITY

Complex Specs Invite Disaster. . . .

Just as people are uniformly against sin, users of equipment are uniformly against unreliability. In each case, the evil opposed is often ill-defined.

Major efforts are under way to find a suitable definition for reliability. Reliability engineers are commonplace. Speeches on the need for reliability are made at nearly every meeting and conference, and almost every equipment contract demands something concerning it. An exceedingly desirable quality of equipment, it remains elusive.

Reliability is not a two-sided problem; it is at least tetrahedral. On one surface is the user. To him unreliable equipment is equipment not working when it is needed. To supply and maintenance men it is equipment difficult to keep operating. To the inspector it fails to pass the tests of the specification. To the sales force it means no more orders. There are many more sides to the problem, but in its center, bouncing from side to side, is the designer.

For the purposes of this discussion, reliability is defined from the user's viewpoint: to be reliable the equipment must work when needed.

It is understood that the designer has a major responsibility in contributing to the achievement of reliable equipment. Not so often recognized is that the user has a responsibility in intelligent planning of specifications which the designer must carry out to achieve the user's concept of reliability.

We would like to discuss some things *both* the user and the designer might do to have equipment operating in the right place at the right time. This month we will discuss the role of the user; next month that of the designer.

Nature demands payment in full; you can't get something for nothing. If the number of functions of equipment is increased, equipment complexity increases. One of the surest roads to non-operation is complexity. Take any approach—statistical, experimental—the answer is the same.

No one desiring reliable performance has ever deliberately specified unreliable equipment, yet many an ultimate user, unaware of the dangers of complexity, has invited disaster in his specifications. The operational behavior of the equipment should be no more complicated than is required. Determination of what is required is subtle and an important design function in its own right. However, it is a process that must be gone through before a piece of hardware is specified.

The responsibility for getting the least complex functional specifications for the equipment to do the job at hand belongs to the user. Specification writing is treacherous. When going from requirement to specification, the user may lose track of his objective. To aid the user in avoiding some of the pitfalls, we will take an unorthodox viewpoint. Let's consider a few ways to specify unreliable equipment:

Ask for more functions than you need. Take advantage of current skills to get a really splendid design, one you can be proud of. For example, ask for automation.

Ask for better performance than you need or want. Double sensitivity, triple resolution, quadruple gain. How can you go wrong? Designers will aim at your goals, skillfully using delicate components noted for high performance.

Demand sub-sub-miniaturization even though not required by environment. Don't accept standardized components. Have them made smaller. For instance, by halving the size of electronic equipment for a radar station in Alaska you could save air shipment on a great part of the lumber that would have been required to house the equipment. The only problem would be in housing a few extra field engineers needed to maintain the equipment.

Tell the designer which components to use. Demand recently developed components. For instance, if you read about a developmental transistor for use at 3 kmc, insist that it be used in your equipment. After all, transistors are said to be reliable. Demand classes of components with acclaimed reliability. Ignore the ranks of those who warn that the first production runs of ruggedized units are often less satisfactory than the prototypes.

Overspecify the environmental conditions and tests. You can be sure that equipment designed for extreme environmental conditions will be good in less stringent field situations as long as it remains operable.

Classify operational requirements and don't give the designer a need to know. By being secretive with curious designers you can get exactly what you specify. You will also avoid the troublesome burden of discussing changes in specifications suggested by the designer.

This is hardly a complete list of the steps by which the man who writes the operational specifications can damage the cause of reliability. But it can help to show that he, as well as the designer, can contribute significantly to ultimate reliability of the equipment.

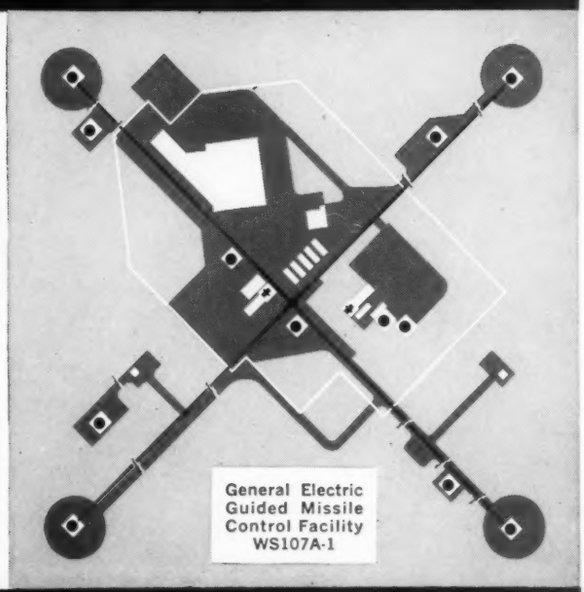
The designer's burden is also a great one. He not only has the immediate responsibility for the design of equipment to specifications but often has much to say about the specifications before they are written. The role of the designer will be discussed in next issue's column.

GRADUATE EE'S: GENERAL ELECTRIC DISCLOSES HIGH PRIORITY PROGRAM FOR ATLAS

GUIDANCE SYSTEM. MANY POSITIONS OPEN IN ELECTRONIC MISSILE TECHNIQUES=

ACCURACIES ON ORDER OF 1 PART IN 10 MILLION

required for portions of G.E.'s ICBM ATLAS Guidance System



Delivering an ICBM over a > 5000 mile trajectory into the target area demands a guidance system of unprecedented accuracy—and this is the calibre of the electronic system General Electric engineers are creating for ATLAS.

But achieving designated accuracies and reliabilities in the laboratory is not enough. *These high standards must be maintained in actual operational environments, with virtually no interruption or degradation.*

CAREERS IN STEP WITH THE FUTURE

Engineers who join the Missile Guidance Product Section of G.E. are doing more than hastening development of one of the nation's most urgent programs—guidance for ATLAS. As Manager of the Section Richard L. Shetler states: *"With this job behind us, there will remain no significant obstacle to the practical guidance and navigation of other space vehicles."*

PROGRAM ACCELERATION OPENS UP WIDE RANGE OF POSITIONS IN:

- Systems analysis, evaluation & integration
- Systems and component reliability
- Transistorized circuits, pulse circuitry, IF-Video circuits
- RF and Microwave components & plumbing
- Communications control devices
- Doppler radar design & development
- Digital data processing techniques, data transmission involving D & D of ground-based & airborne antennae, transmitters, receivers; application of transducers, transponders, etc.
- Test operations, including planning, range instrumentation & test execution; development & application of automatic test equipment

If you feel that your special skills and interests fit you to work in any of the above areas, why not write us in detail? Qualified candidates will be invited to visit our facilities to meet with technical managers and gain first hand knowledge of the living advantages of our locations at Syracuse and Utica, N. Y.

Write in complete confidence to Mr. E. A. Smith, Room 4J

MISSILE GUIDANCE PRODUCT SECTION

GENERAL ELECTRIC

Court Street, Syracuse, N.Y.

FOR MORE INFORMATION CIRCLE 29 ON INQUIRY CARD

AMM

ANTI MISSILE MISSILE

WHEN "MINUTES" COUNT

SYNCHRO FUNCTION	CPPC TYPE	PRIMARY						D. C. RESISTANCE		IMPEDANCE			Max. Null Voltage (MV)	ACCURACY Max. Error (Min.)
		Input Voltage (400~)	Input Current (Amps.)	Input Power (Watts)	Output Voltage (Volts)	Sensitivity (MV/deg.)	Phase Shift (deg. lead)	Rotor (Ohms)	Stator (Ohms)	Zro (Ohms)	Zso (Ohms)	Zrss (Ohms)		
Torque Transmitter	CGC-8-A-7	26	.100	.5	11.8	206	8	37	12	54 + j260	12 + j45	80 + j20	30	7
Control Transformer	CTC-8-A-1	11.8	.090	.2	23.5	410	9	150	24	212 + j684	22 + j115	245 + j60	30	7
Control Transformer	CTC-8-A-4	11.8	.029	.08	22.5	390	8	389	64	560 + j1860	90 + j340	640 + j190	30	7
Torque Receiver	CRC-8-A-1	26	.100	.5	11.8	206	8	37	12	54 + j260	12 + j45	80 + j20	30	30 sp.
Electrical Resolver	CSC-8-A-1	26	.038	.42	10.8	190	20	230	27	286 + j620	45 + j148	350 + j75	30	7
Electrical Resolver	CSC-8-A-4	26	.038	.42	26	454	20	230	170	286 + j620	250 + j830	350 + j75	30	7
Control Differential	CDC-8-A-1	11.8	.085	.21	11.8	206	9	36	25	38 + j122	27 + j120	48 + j14	30	7
Vector Resolver	CVC-8-A-1	26	.057	.34	11.8	206	10.2	78	27	103 + j440	8 + j30		30	7

ACTUAL SIZE

Count on CPPC Synchros

In the above diagram, which simulates the attack of an ICBM and its destruction by an Anti-Missile Missile, only 20 minutes will elapse from the time advanced radar picks up the ICBM at point *a* and the time ICBM reaches its target. These are a vital 20 minutes.

In these 20 minutes the path of the ICBM must be computed with extreme accuracy and the intercepting path of the Anti-Missile Missile computed equally accurately.

Minutes count—both minutes of time and minutes of maximum error in the computing devices.

Clifton Precision synchros offer highest accuracies in standard synchro units. Special units are available which eliminate, for practical purposes, all synchro error. In addition, reliability standards are the most stringent we can devise and still mass produce synchros.

Delivery time has been shortened and production capacity approximately doubled with the opening of our Western Division at Colorado Springs, Colorado.

For full information, call or write Sales Department, HIlltop 9-1200 (Suburban Philadelphia) or our representatives.

LOOK TO CPPC FOR SYNCHRO PROGRESS

VISIT OUR HOSPITALITY SUITE AT I.R.E. • Studio K, Barbizon-Plaza Hotel

CLIFTON PRECISION PRODUCTS CO., INC. cppc Clifton Heights, Pa.